PATENT ABSTRACTS OF JAPAN

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INOUE RIYUUTSUKASA

(30)Priority
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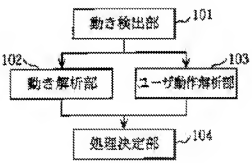
(54) OPERATION INSTRUCTION OUTPUT DEVICE GIVING OPERATION INSTRUCTION IN ACCORDANCE WITH KIND OF USER'S ACTION AND COMPUTER-READABLE RECORDING MEDIUM

(57)Abstract:
PROBLEM TO BE SOLVED: To obtain an operation instruction output device which converts an operation instruction corresponding to the movement of a device body by detecting the movement of the device body and distinguishing the kind of a user's action which generated the action.
SOLUTION: A movement detecting part 101 detects the movement of a device body. A movement analyzing part 102 analyzes a movement direction, strength and the number of times from the detected movement. A user's action analyzing part 103 finds the frequency distribution of the movement from the detected movement and analyzes the kind of the user's action. A processing deciding part 104 has a storing part which stores an operation instruction corresponding to the movement direction of the device, etc., and the kind of the user's action and outputs an operation instruction corresponding to analysis results of the parts 102 and 103 to an information processor.



US006369794B1

(12) **United States Patent**
Sakurai et al.

(10) **Patent No.: US 6,369,794 B1**
(45) **Date of Patent: Apr. 9, 2002**

(54) **OPERATION INDICATION OUTPUTTING DEVICE FOR GIVING OPERATION INDICATION ACCORDING TO TYPE OF USER'S ACTION**

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(73) Assignee: **Matsushita Electric Industrial Co., Ltd.**, Kadoma (JP)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

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(30) **Foreign Application Priority Data**

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(51) **Int. Cl.**[7] **G09G 5/00**

(52) **U.S. Cl.** **345/156**; 379/433.04

(58) **Field of Search** 345/156, 157, 343/158, 382/276, 280; 379/433.04

(56) **References Cited**

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Primary Examiner—Richard Hjerpe
Assistant Examiner—Ronald Laneau
(74) *Attorney, Agent, or Firm*—Wenderoth, Lind & Ponack, L.L.P.

(57) **ABSTRACT**

A motion detecting unit detects a motion of an operation indication outputting device. A motion analyzing unit analyzes a direction, strength, and number of occurrence of the detected motion. A user action analyzing unit analyzes a type of a user's action by obtaining a frequency distribution from the detected motion. An operation determining unit includes a storing unit which stores operation indications that each correspond to a type of the user's action and a direction and other attributes of a motion of the operation indication outputting device caused by the user's action, and outputs an operation indication corresponding to the analysis results by the motion analyzing unit and user action analyzing unit to an information processing apparatus.

20 Claims, 22 Drawing Sheets

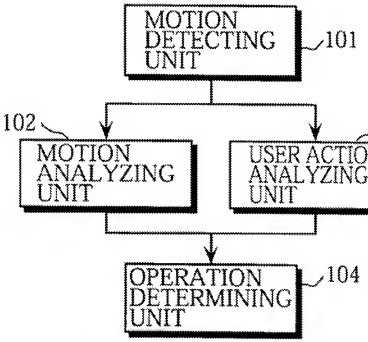


FIG. 1

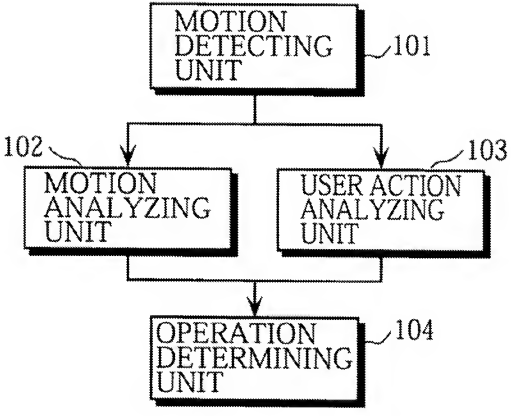

MOTION DETECTING UNIT
101
102
MOTION ANALYZING UNIT
103
USER ACTION ANALYZING UNIT
OPERATION DETERMINING UNIT
104

FIG. 2

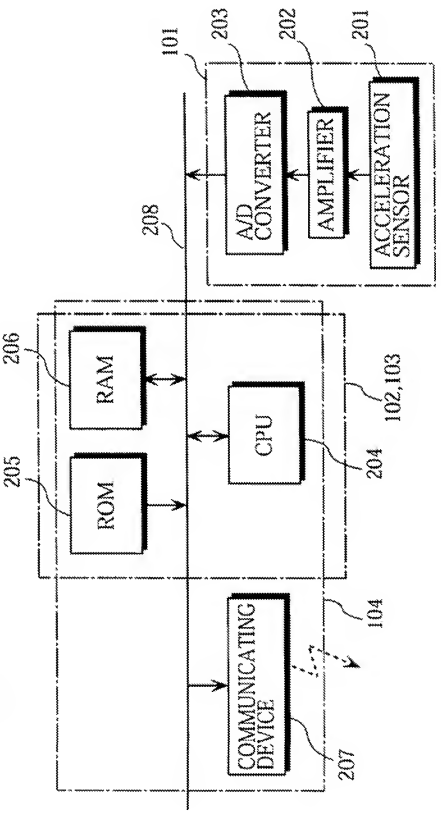

101
203
202
201
208
A/D CONVERTER
AMPLIFIER
ACCELERATION SENSOR
206
RAM
205
ROM
CPU
204
102,103
104
COMMUNICATING DEVICE
207

FIG. 3

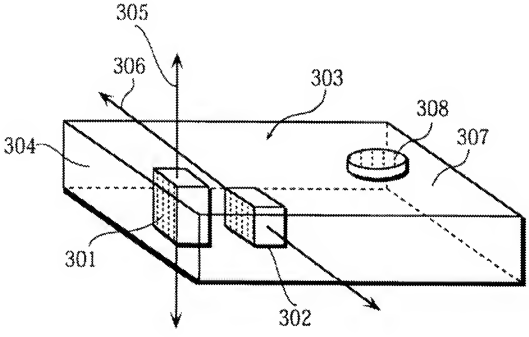


FIG. 4A

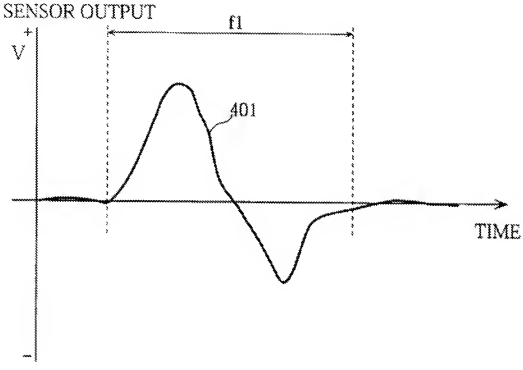


FIG. 4B

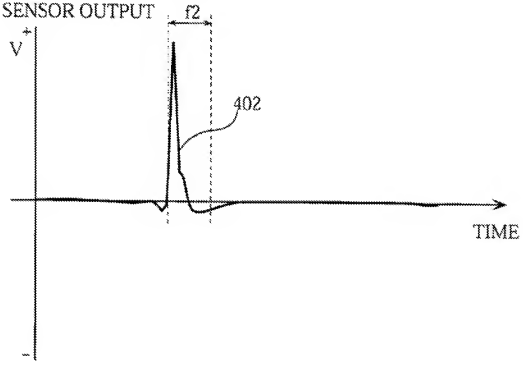


FIG. 5

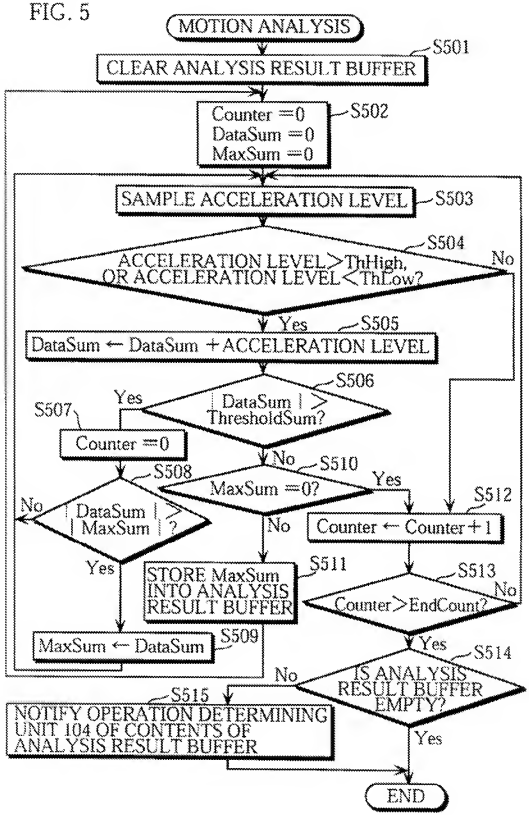

MOTION ANALYSIS
S501
CLEAR ANALYSIS RESULT BUFFER
Counter =0
DataSum =0
MaxSum =0
S502
SAMPLE ACCELERATION LEVEL
S503
ACCELERATION LEVEL>ThHigh, OR ACCELERATION LEVEL<ThLow?
S504
No
Yes
S505
DataSum ← DataSum +ACCELERATION LEVEL
S506
| DataSum | > ThresholdSum?
Yes
S507
Counter =0
No
S510
MaxSum =0?
Yes
S512
Counter ← Counter+1
S508
| DataSum | > | MaxSum | ?
No
Yes
No
S511
STORE MaxSum INTO ANALYSIS RESULT BUFFER
S513
Counter>EndCount?
No
Yes
MaxSum ← DataSum
S509
S514
IS ANALYSIS RESULT BUFFER EMPTY?
No
Yes
S515
NOTIFY OPERATION DETERMINING UNIT 104 OF CONTENTS OF ANALYSIS RESULT BUFFER
END

FIG. 6

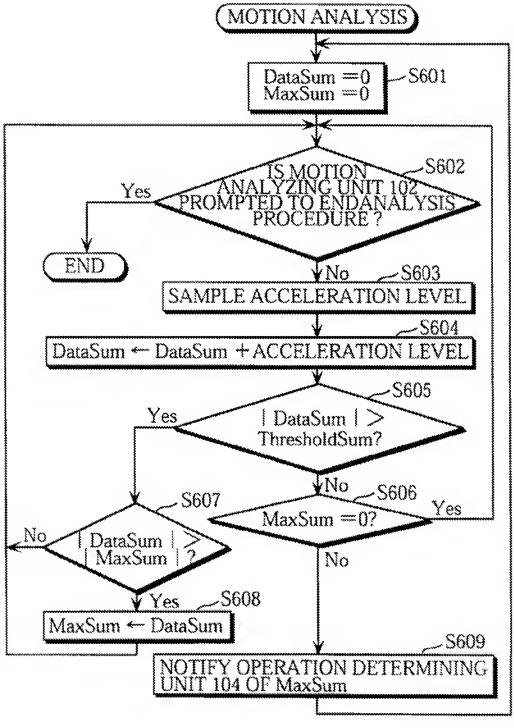

MOTION ANALYSIS
DataSum =0
MaxSum =0
S601
IS MOTION ANALYZING UNIT 102 PROMPTED TO ENDANALYSIS PROCEDURE ?
S602
Yes
END
No
S603
SAMPLE ACCELERATION LEVEL
S604
DataSum ← DataSum +ACCELERATION LEVEL
S605
Yes
| DataSum | > ThresholdSum?
No
S606
MaxSum =0?
Yes
No
S607
No
| DataSum | > | MaxSum | ?
Yes
S608
MaxSum ← DataSum
S609
NOTIFY OPERATION DETERMINING UNIT 104 OF MaxSum

FIG. 7A

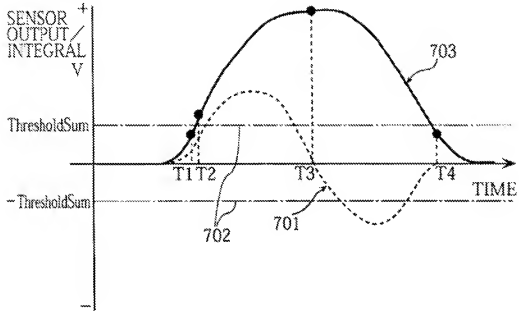

SENSOR OUTPUT/ INTEGRAL V
+
ThresholdSum
-ThresholdSum
−
T1 T2
T3
T4
TIME
703
702
701

FIG. 7B

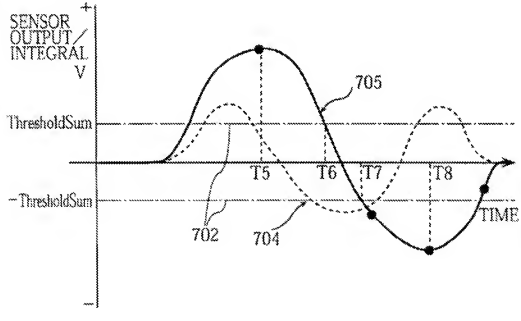

SENSOR OUTPUT/ INTEGRAL V
+
ThresholdSum
-ThresholdSum
−
T5
T6
T7
T8
TIME
705
702
704

FIG. 8

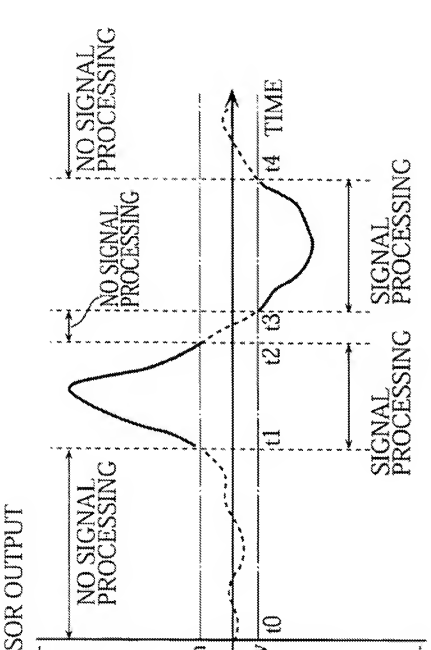

SENSOR OUTPUT
+
V
−
ThHigh
ThLow
NO SIGNAL PROCESSING
NO SIGNAL PROCESSING
NO SIGNAL PROCESSING
SIGNAL PROCESSING
SIGNAL PROCESSING
t0
t1
t2
t3
t4
TIME

FIG. 9

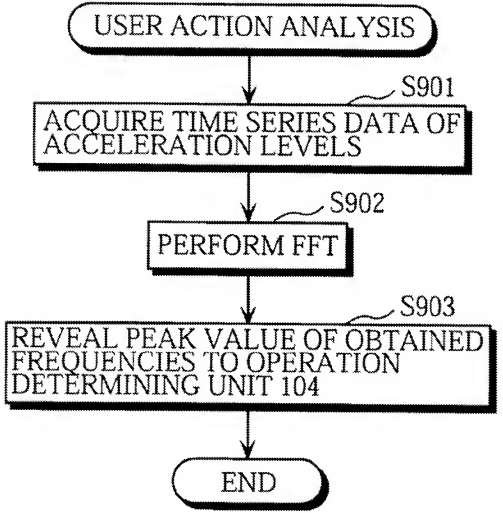

USER ACTION ANALYSIS
S901
ACQUIRE TIME SERIES DATA OF ACCELERATION LEVELS
S902
PERFORM FFT
S903
REVEAL PEAK VALUE OF OBTAINED FREQUENCIES TO OPERATION DETERMINING UNIT 104
END

FIG. 10A

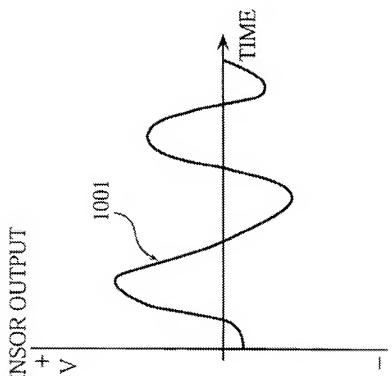


FIG. 10B

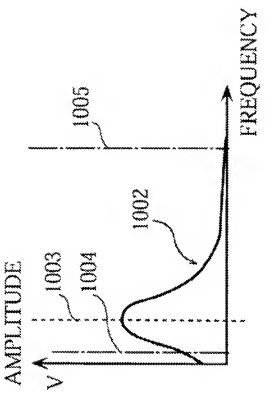


FIG. 11A

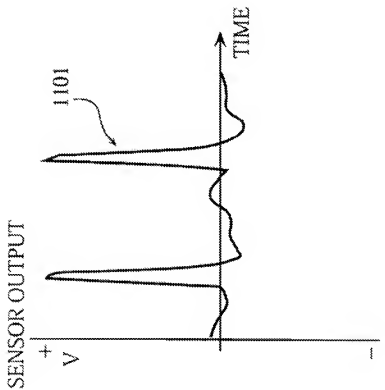


FIG. 11B

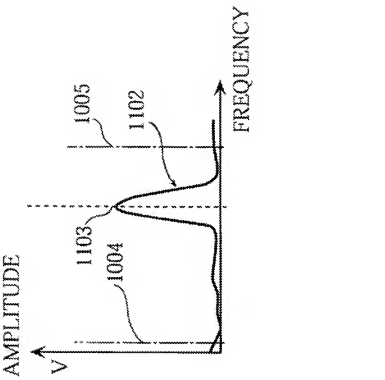


FIG. 12

1209 1201 1207 1208 1204 1202 1205 1206 1203

SENSOR 2 \ SENSOR 1		0	LOW FREQUENCY POSITIVE DIRECTION	LOW FREQUENCY NEGATIVE DIRECTION	LOW FREQUENCY CONTINUITY	HIGH FREQUENCY POSITIVE DIRECTION	HIGH FREQUENCY NEGATIVE DIRECTION	HIGH FREQUENCY CONTINUITY
	0		UP	DOWN	REEXECUTE OPERATION	ZOOM IN	ZOOM OUT	SELECT
LOW FREQUENCY	POSITIVE DIRECTION	RIGHT	UPPER RIGHT	LOWER RIGHT	REEXECUTE OPERATION	ZOOM IN	ZOOM OUT	SELECT
LOW FREQUENCY	NEGATIVE DIRECTION	LEFT	UPPER LEFT	LOWER LEFT	REEXECUTE OPERATION	ZOOM IN	ZOOM OUT	SELECT
LOW FREQUENCY	CONTINUITY	CANCEL OPERATION	CANCEL OPERATION	CANCEL OPERATION		CANCEL OPERATION	CANCEL OPERATION	
HIGH FREQUENCY	POSITIVE DIRECTION	NEXT PAGE	NEXT PAGE	NEXT PAGE	REEXECUTE OPERATION			SELECT
HIGH FREQUENCY	NEGATIVE DIRECTION	PREVIOUS PAGE	PREVIOUS PAGE	PREVIOUS PAGE	REEXECUTE OPERATION			SELECT
HIGH FREQUENCY	CONTINUITY	TOP PAGE	TOP PAGE	TOP PAGE		TOP PAGE	TOP PAGE	

FIG. 13

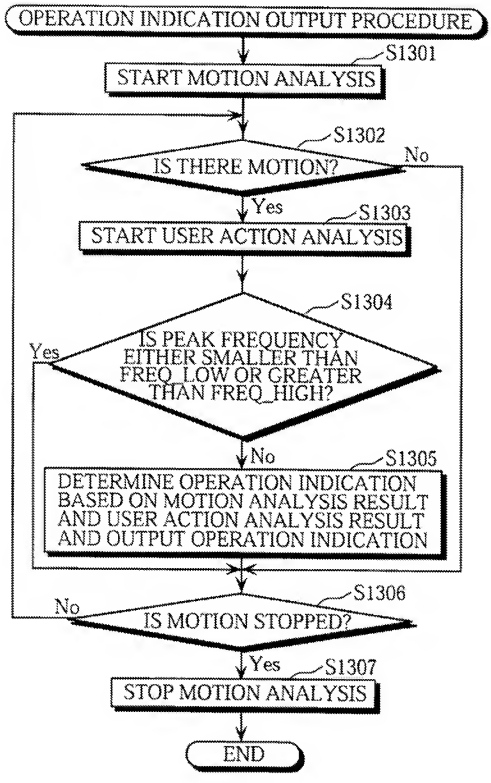

OPERATION INDICATION OUTPUT PROCEDURE
S1301
START MOTION ANALYSIS
S1302
IS THERE MOTION?
No
Yes
S1303
START USER ACTION ANALYSIS
S1304
IS PEAK FREQUENCY EITHER SMALLER THAN FREQ_LOW OR GREATER THAN FREQ_HIGH?
Yes
No
S1305
DETERMINE OPERATION INDICATION BASED ON MOTION ANALYSIS RESULT AND USER ACTION ANALYSIS RESULT AND OUTPUT OPERATION INDICATION
S1306
IS MOTION STOPPED?
No
Yes
S1307
STOP MOTION ANALYSIS
END

FIG. 14

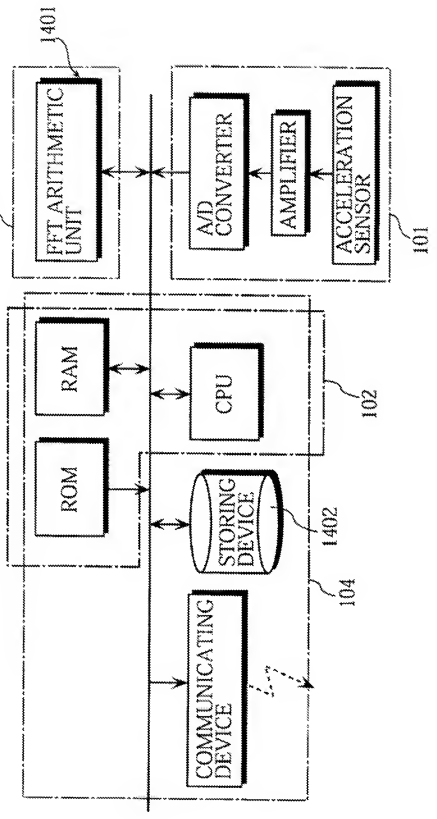

1401
FFT ARITHMETIC UNIT
103
A/D CONVERTER
AMPLIFIER
ACCELERATION SENSOR
101
ROM
RAM
CPU
102
STORING DEVICE
1402
104
COMMUNICATING DEVICE

FIG. 15

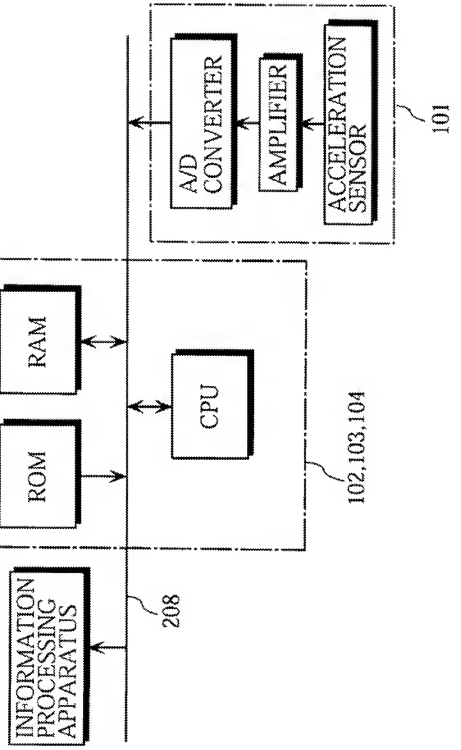

INFORMATION PROCESSING APPARATUS
208
ROM
RAM
CPU
102,103,104
A/D CONVERTER
AMPLIFIER
ACCELERATION SENSOR
101

FIG. 16

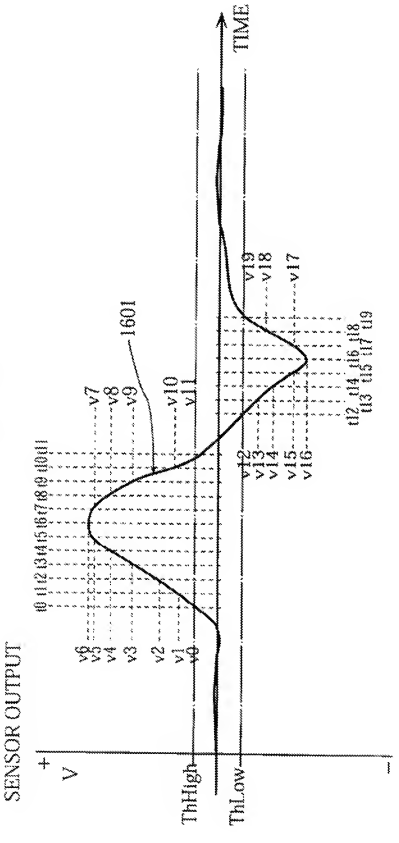

SENSOR OUTPUT
+
V
−
ThHigh
ThLow
TIME
1601
v1
v2
v3
v4
v5
v6
v7
v8
v9
v10
v11
v12
v13
v14
v15
v16
v17
v18
v19
t0 t1 t2 t3 t4 t5 t6 t7 t8 t9 t10 t11
t12 t14 t16 t18
t13 t15 t17 t19

FIG. 17

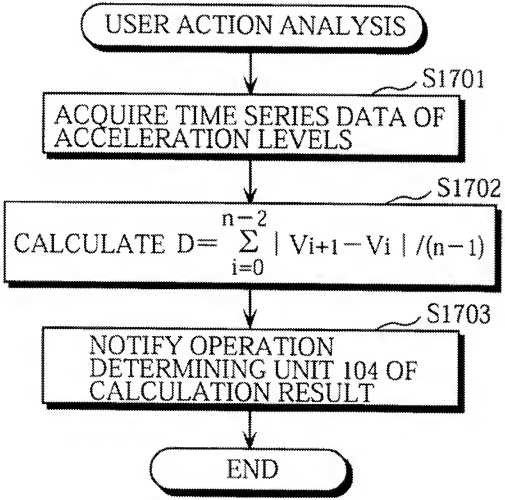

USER ACTION ANALYSIS
S1701
ACQUIRE TIME SERIES DATA OF ACCELERATION LEVELS
S1702
CALCULATE $D=\sum_{i=0}^{n-2} |Vi+1-Vi|/(n-1)$
S1703
NOTIFY OPERATION DETERMINING UNIT 104 OF CALCULATION RESULT
END

FIG. 18

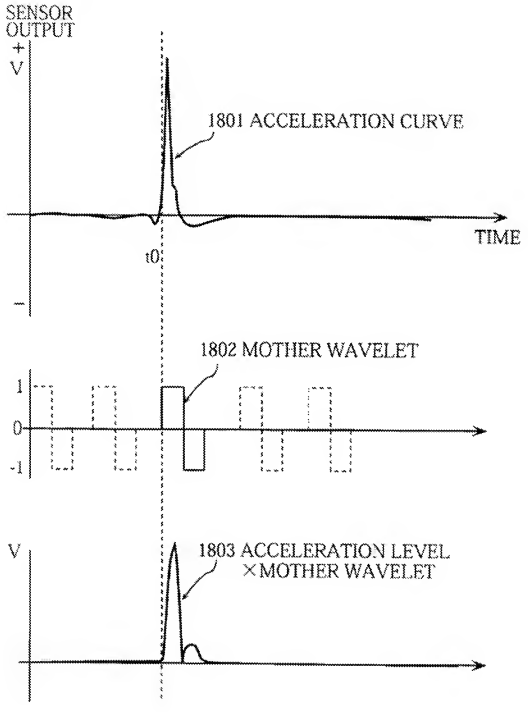

SENSOR OUTPUT
+
V
1801 ACCELERATION CURVE
TIME
t0
−
1802 MOTHER WAVELET
1
0
-1
V
1803 ACCELERATION LEVEL
×MOTHER WAVELET

FIG. 19

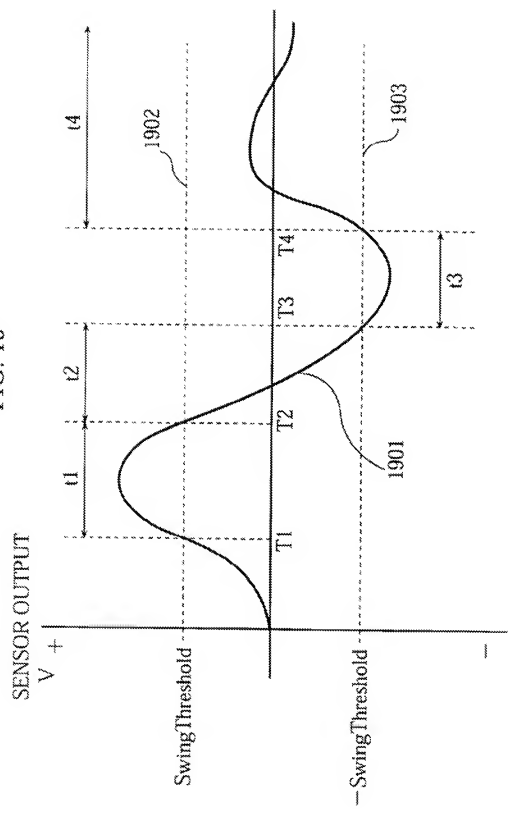

SENSOR OUTPUT
V
+
−
SwingThreshold
−SwingThreshold
t1
t2
t3
t4
T1
T2
T3
T4
1901
1902
1903

FIG. 20

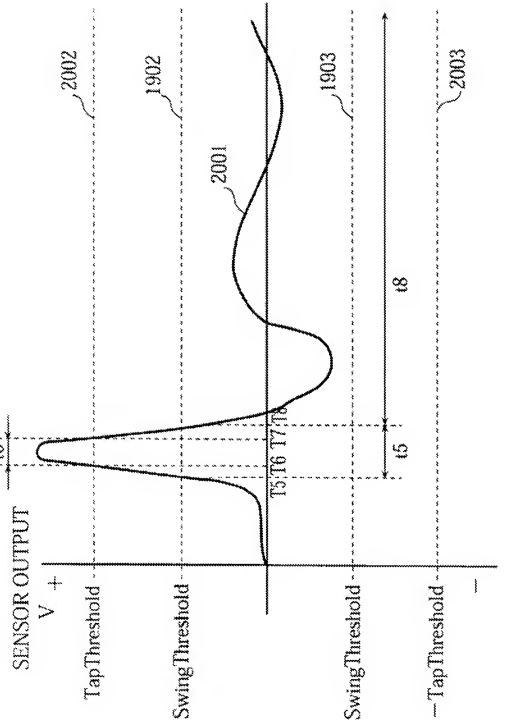

SENSOR OUTPUT
V +
TapThreshold
SwingThreshold
—SwingThreshold
—TapThreshold
—
2002
1902
2001
1903
2003
t6
T5 T6 T7 T8
t5
t8

FIG. 21

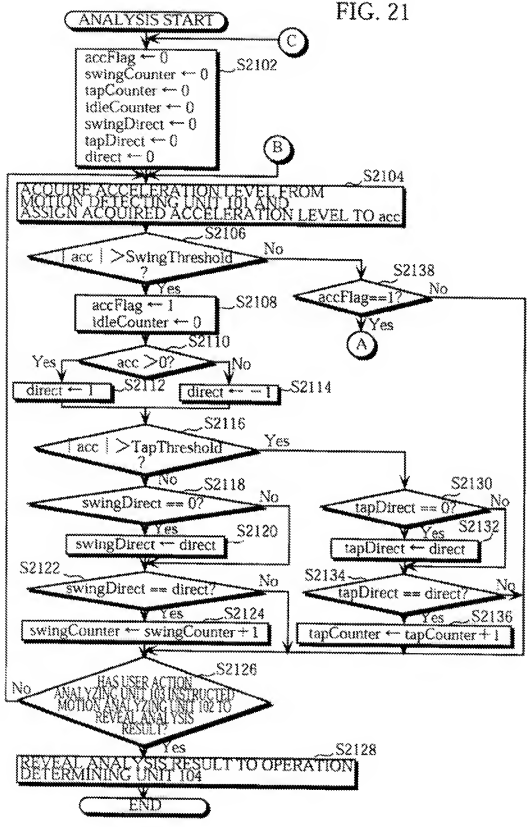
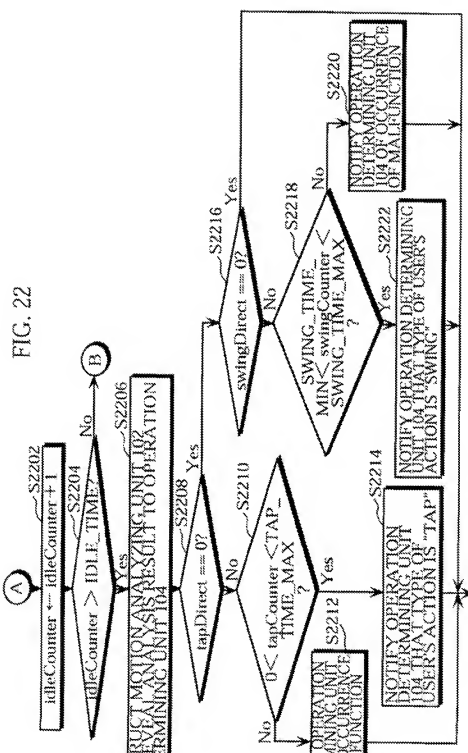

ANALYSIS START
C
accFlag ← 0
swingCounter ← 0
tapCounter ← 0
idleCounter ← 0
swingDirect ← 0
tapDirect ← 0
direct ← 0
S2102
B
S2104
ACQUIRE ACCELERATION LEVEL FROM MOTION DETECTING UNIT 101 AND ASSIGN ACQUIRED ACCELERATION LEVEL TO acc
S2106
| acc | >SwingThreshold ?
No
Yes
S2138
accFlag==1?
No
Yes
A
accFlag ← 1
idleCounter ← 0
S2108
S2110
acc >0?
Yes
No
direct ← 1
S2112
direct ← −1
S2114
S2116
| acc | >TapThreshold ?
Yes
No
S2118
swingDirect == 0?
No
Yes
swingDirect ← direct
S2120
S2122
swingDirect == direct?
No
Yes
S2124
swingCounter ← swingCounter + 1
S2130
tapDirect == 0?
No
Yes
S2132
tapDirect ← direct
S2134
tapDirect == direct?
No
Yes
S2136
tapCounter ← tapCounter + 1
S2126
HAS USER ACTION ANALYZING UNIT 103 INSTRUCTED MOTION ANALYZING UNIT 102 TO REVEAL ANALYSIS RESULT?
No
Yes
S2128
REVEAL ANALYSIS RESULT TO OPERATION DETERMINING UNIT 104
END

FIG. 22


A
S2202
idleCounter ← idleCounter + 1
S2204
idleCounter > IDLE_TIME?
No
B
Yes
S2206
INSTRUCT MOTION ANALYZING UNIT 102 TO REVEAL ANALYSIS RESULT TO OPERATION DETERMINING UNIT 104
S2208
tapDirect == 0?
Yes
No
S2210
0< tapCounter <TAP_TIME_MAX ?
No
Yes
S2212
NOTIFY OPERATION DETERMINING UNIT 104 OF OCCURRENCE OF MALFUNCTION
S2214
NOTIFY OPERATION DETERMINING UNIT 104 THAT USER'S ACTION IS "TAP"
C
S2216
swingDirect == 0?
Yes
No
S2218
SWING_TIME_MIN< swingCounter < SWING_TIME_MAX ?
No
Yes
S2220
NOTIFY OPERATION DETERMINING UNIT 104 OF OCCURRENCE OF MALFUNCTION
S2222
NOTIFY OPERATION DETERMINING UNIT 104 THAT TYPE OF USER'S ACTION IS "SWING"

OPERATION INDICATION OUTPUTTING DEVICE FOR GIVING OPERATION INDICATION ACCORDING TO TYPE OF USER'S ACTION

This application is based on an application No. 10-254787 filed in Japan, the content of which is hereby incorporated by reference.

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to an operation indicating outputting device for detecting a motion of the operation indication outputting device caused by a user's action and outputting an operation indication according to the detection result.

2. Description of the Prior Art

In virtual reality and other technologies, display control and operation indication are performed by digitally coding a movement of a person with position sensors (e.g. 3SPACE system made by Polhemus, Inc.) which use data gloves or magnetic transducing techniques and inputting generated codes into a computer. With the recent development of smaller and more accurate motion detection sensors such as acceleration sensors, several techniques are disclosed whereby such sensors are incorporated into a portable information processing apparatus to detect a motion of the body of the apparatus so that information processing is performed according to the detected motion.

For instance, Japanese Laid-Open Patent Application 9-4208 discloses a device that is equipped with a sensor for detecting a motion of the device and a motion analyzing unit for determining a direction, travel, and number of occurrence of movement or rotation of the device based on data outputted from the sensor, thereby designating the contents of processing according to the determined direction, travel, and number of occurrence of the motion. When this device is vertically and/or horizontally moved, the inside sensor detects the motion and outputs data of the motion, based on which the motion analyzing unit calculates the vertical travel and horizontal travel of the device. As a result, a display such as text on a liquid crystal display panel is scrolled sideways or up and down by a number of pixels corresponding to the calculated travel, or a cursor displayed on the display panel is moved sideways or up and down by the number of pixels.

However, this conventional device does not distinguish certain types of actions such as "swing" and "tap" made by a user against the body of the device, so that a selection of operations which can be designated is limited. Besides, when the user accidentally bumps the device against something while moving the device, an operation which the user does not intend may be designated by mistake.

SUMMARY OF THE INVENTION

In view of the above problems, the present invention aims to provide an operation indication outputting device that can give a wide variety of operation indications while preventing malfunctions, and a computer-readable storing medium that stores a program for realizing the function of the operation indication outputting device.

The stated object can be fulfilled by an operation indication outputting device for outputting an operation indication to an information processing apparatus to have the information processing apparatus perform processing based on the outputted operation indication, the operation indication outputting device including: a storing unit for storing operation indications that each correspond to a combination of a type of a user's action and at least one of a direction, a strength, and a number of occurrence of a motion of the operation indication outputting device caused by the user's action; a motion detecting unit for detecting a motion of the operation indication outputting device caused by the user's action; a motion analyzing unit for analyzing at least one of a direction, a strength, and a number of occurrence of the detected motion; a user action analyzing unit for analyzing a type of the user's action that causes the detected motion; and an outputting unit for reading, from the storing unit, an operation indication corresponding to a combination of an analysis result by the motion analyzing unit and an analysis result by the user action analyzing unit, and outputting the read operation indication to the information processing apparatus.

With this construction, the operation indication outputting device can have the information processing apparatus perform various processing by identifying the type of the action made by the user against the operation indication outputting device.

Here, the motion detecting unit may detect acceleration levels of the motion of the operation indication outputting device over time, wherein the motion analyzing unit analyzes at least one of the direction, the strength, and the number of occurrence of the motion by integrating, with respect to time, the acceleration levels outputted from the motion detecting unit.

With this construction, the motion of the operation indication outputting device can be detected with low-priced acceleration sensors, and at least one of the direction, strength, and number of occurrence of the motion can be analyzed by a simple procedure.

Here, the user action analyzing unit may include a fast Fourier transform analyzing unit for obtaining a frequency distribution by performing a fast Fourier transform on a curve produced by graphing the acceleration levels outputted from the motion detecting unit against time, to analyze the type of the user's action.

With this construction, the type of the user's action can be identified with respect to frequency by analyzing the frequency distribution.

Here, the user action analyzing unit may further include an output prohibiting unit for prohibiting the outputting unit to output the operation indication if a peak value in the obtained frequency distribution is any of below a first frequency and above a second frequency.

With this construction, it is possible to prevent the information processing apparatus from performing wrong processing in the event of an accident such as the user dropping the operation indication outputting device.

Here, the user action analyzing unit may include a differential analyzing unit for differentiating, according to a predetermined equation, a curve produced by graphing the acceleration levels outputted from the motion detecting unit against time, to analyze the type of the user's action.

With this construction, the type of the user's action can be judged by a simple procedure.

Here, the user action analyzing unit may further include an output prohibiting unit for prohibiting the outputting unit to output the operation indication if a mean value of differential values calculated by the differential analyzing unit is any of below a first threshold value and above a second threshold value.

With this construction, it is possible to prevent the information processing apparatus from performing wrong processing in the event of an accident such as the user dropping the operation indication outputting device.

Here, the user action analyzing unit may include a wavelet transform analyzing unit for detecting specific frequency components by performing a wavelet transform on a curve produced by graphing the acceleration levels outputted from the motion detecting unit against time, to analyze the type of the user's action.

With this construction, the type of the user's action can be accurately specified by analyzing frequency composition.

Here, the storing unit may further store operation indications that each correspond to an order of a plurality of types of the user's actions, wherein the user action analyzing unit further includes an action sequence analyzing unit for analyzing types of the user's actions that cause the motion, according to an order in which the detected specific frequency components appear, and wherein the outputting unit includes an order-corresponding operation indicating unit for reading, from the storing unit, an operation indication corresponding to an order of the types of the user's actions analyzed by the action sequence analyzing unit, and outputting the read operation indication to the information processing apparatus.

With this construction, a choice of operation indications which can be outputted to the information processing apparatus is further diversified.

Here, the user action analyzing unit may include a time analyzing unit for measuring, for each of a plurality of reference values, time during which the reference value is exceeded by absolute values of a sequence of acceleration levels among the acceleration levels outputted from the motion detecting unit, to analyze the type of the user's action.

With this construction, the type of the user's action can be specified with reference to the plurality of reference values.

Here, the user action analyzing unit may further include an output prohibiting unit for prohibiting the outputting unit to output the operation indication if at least one of absolute values of the outputted acceleration levels is any of below a first threshold value and above a second threshold value.

With this construction, it is possible to prevent the information processing apparatus from performing wrong processing in the event of an accident such as the user dropping the operation indication outputting device.

Here, the motion detecting unit may detect acceleration levels of the motion of the operation indication outputting device over time, wherein for each of a plurality of reference values, when the reference value is exceeded by absolute values of a sequence of acceleration levels among the acceleration levels outputted from the motion detecting unit, the motion analyzing unit analyzes a sign of an acceleration level whose absolute value first exceeds the reference value in the sequence of acceleration levels, and measures time during which the reference value is exceeded by the absolute values of the sequence of acceleration levels, thereby analyzing at least one of the direction, the strength, and the number of occurrence of the motion, and wherein the user action analyzing unit analyzes the type of the user's action based on the time measured by the motion analyzing unit.

With this construction, the type of the user's action can be identified by simply measuring a period for each of the plurality of reference values during which absolute values of detected acceleration levels exceed the reference value. In doing so, the operation indication outputting device can have the information processing apparatus execute various processing.

Here, the plurality of reference values may be made up of a first reference value and a second reference value larger than the first reference value, wherein the user action analyzing unit includes an output prohibiting unit for prohibiting the outputting unit to output the operation indication, any of if time during which the first reference value is exceeded is shorter than predetermined first time and if time during which the second reference value is exceeded is longer than predetermined second time.

With this construction, it is possible to prevent the information processing apparatus from performing wrong processing in the event of an accident such as the user dropping the operation indication outputting device.

Here, the first reference value may be set at a value corresponding to an acceleration level which is to be detected when the user swings the operation indication outputting device, wherein the second reference value is set at a value corresponding to an acceleration level which is to be detected when the user taps the operation indication outputting device, and wherein the user action analyzing unit analyzes whether the type of the user's action is "swing" or "tap".

With this construction, the type of the user's action can be specified as "swing" or "tap" by setting the first and second reference values respectively at values corresponding to, for example, 1 G and 2.5 G (G denotes the acceleration of gravity).

Here, the motion detecting unit may detect angular acceleration levels of the motion of the operation indication outputting device over time, wherein the motion analyzing unit analyzes at least one of the direction, the strength, and the number of occurrence of the motion by integrating, with respect to time, the angular acceleration levels outputted from the motion detecting unit.

With this construction, the operation indication outputting device can also analyze a rotary motion originated from the user's wrist when the user rotates the operation indication outputting device by hand, thereby further diversifying a choice of operation indications which can be outputted to the information processing apparatus.

Here, the user action analyzing unit may include a fast Fourier transform analyzing unit for obtaining a frequency distribution by performing a fast Fourier transform on a curve produced by graphing the angular acceleration levels outputted from the motion detecting unit against time, to analyze the type of the user's action.

With this construction, the type of the user's action can be identified on the basis of an analysis of the frequency distribution.

Here, the motion detecting unit may detect angular acceleration levels of the motion of the operation indication outputting device over time, wherein for each of a plurality of reference values, when the reference value is exceeded by absolute values of a sequence of angular acceleration levels among the angular acceleration levels outputted from the motion detecting unit, the motion analyzing unit analyzes a sign of an angular acceleration level whose absolute value first exceeds the reference value in the sequence of angular acceleration levels, and measures time during which the reference value is exceeded by the absolute values of the sequence of angular acceleration levels, thereby analyzing at least one of the direction, the strength, and the number of occurrence of the motion, and wherein the user action

analyzing unit analyzes the type of the user's action based on the time measured by the motion analyzing unit

With this construction, the type of the user's action can be identified by simply measuring a period for each of the plurality of reference values during which absolute values of detected angular acceleration levels exceed the reference value. As a result, the operation indication outputting device can have the information processing apparatus perform various processing.

The stated object can also be fulfilled by an operation indication outputting device which is incorporated into a mobile phone that is an information processing apparatus, wherein a processing mode of the mobile phone is changed according to an operation indication outputted from an outputting unit of the operation indication outputting device.

With this construction, the operability of the mobile phone which incorporates the operation indication outputting device is improved.

The stated object can also be fulfilled by a mobile phone that incorporates an operation indication outputting device for outputting an operation indication to the mobile phone to have the mobile phone perform processing based on the outputted operation indication, the operation indication outputting device including: a storing unit for storing operation indications that each correspond to a combination of a type of a user's action and at least one of a direction, a strength, and a number of occurrence of a motion of the operation indication outputting device caused by the user's action; a motion detecting unit for detecting a motion of the operation indication outputting device caused by the user's action; a motion analyzing unit for analyzing at least one of a direction, a strength, and a number of occurrence of the detected motion; a user action analyzing unit for analyzing a type of the user's action that causes the detected motion; and an outputting unit for reading, from the storing unit, an operation indication corresponding to a combination of an analysis result by the motion analyzing unit and an analysis result by the user action analyzing unit, and outputting the read operation indication to the mobile phone, wherein a processing mode of the mobile phone is changed according to the operation indication outputted from the outputting unit.

With this construction, the operability of the mobile phone which incorporates the operation indication outputting device is improved.

The stated object can also be fulfilled by a computer-readable storing medium storing a program executed by an operation indication outputting device that is equipped with a detecting unit for detecting a motion of the operation indication outputting device caused by a user's action and outputs an operation indication to an information processing apparatus to have the information processing apparatus perform processing based on the outputted operation indication, the program including: a motion analyzing step for analyzing at least one of a direction, a strength, and a number of occurrence of the motion detected by the detecting unit; a user action analyzing step for analyzing a type of the user's action that causes the detected motion; and an outputting step for reading, from an storing unit which stores operation indications that each correspond to a combination of a type of the user's action and at least one of a direction, a strength, and a number of occurrence of a motion of the operation indication outputting device caused by the user's action, an operation indication corresponding to a combination of an analysis result obtained in the motion analyzing step and an analysis result obtained in the user action analyzing step, and outputting the read operation indication to the information processing apparatus.

With this construction, the operation indication outputting device equipped with the motion detecting unit can be rendered a device that can output a wide variety of operation indications.

BRIEF DESCRIPTION OF THE DRAWINGS

These and other objects, advantages and features of the invention will become apparent from the following description thereof taken in conjunction with the accompanying drawings that illustrate a specific embodiment of the invention. In the drawings:

FIG. **1** shows the configuration of an operation indication outputting device of the first embodiment of the present invention;

FIG. **2** shows the hardware construction of the operation indication outputting device;

FIG. **3** shows the appearance of the operation indication outputting device and the placement of a motion detecting unit **101**;

FIG. **4**A shows an acceleration curve outputted from an acceleration sensor of the motion detecting unit **101** when the user swings the operation indication outputting device once;

FIG. **4**B shows an acceleration curve outputted from an acceleration sensor of the motion detecting unit **101** when the user taps the operation indication outputting device once;

FIG. **5** is a flowchart showing an example of motion analysis by a motion analyzing unit **102** of the operation indication outputting device;

FIG. **6** is a flowchart showing another example of motion analysis by the motion analyzing unit **102**;

FIG. **7**A shows an integral curve for acceleration levels obtained by the motion analyzing unit **102** when the user swings the operation indication outputting device once;

FIG **7**B shows an integral curve for acceleration levels obtained by the motion analyzing unit **102** when the user swings the operation indication outputting device continuously;

FIG **8** shows threshold values used for acceleration levels outputted by the motion detecting unit **101**,

FIG. **9** is a flowchart showing user action analysis by a user action analyzing unit **103** of the operation indication outputting device;

FIG. **10**A shows an acceleration curve outputted from the motion detecting unit **101** when the user swings the operation indication outputting device;

FIG. **10**B shows a frequency distribution curve obtained by the user action analyzing unit **103** performing a FFT on the acceleration curve in FIG. **10**A,

FIG **11**A shows an acceleration curve outputted from the motion detecting unit **101** when the user taps the operation indication outputting device;

FIG **11**B shows a frequency distribution curve obtained by the user action analyzing unit **103** performing a FFT on the acceleration curve in FIG. **11**A;

FIG. **12** shows the contents of an operation determination table stored in an operation determining unit **104** of the operation indication outputting device;

FIG. **13** is a flowchart showing the overall operation of the operation indication outputting device;

FIG. **14** shows the hardware construction of a variant of the first embodiment;

FIG. **15** shows the hardware construction of a variant of the first embodiment;

FIG. **16** shows the details of user action analysis by the user action analyzing unit **103** of the operation indication outputting device in the second embodiment of the present invention;

FIG. **17** is a flowchart showing the user action analysis by the user action analyzing unit **103** of the second embodiment;

FIG. **18** shows the process of a wavelet transform performed by the user action analyzing unit **103** of the operation indication outputting device in the third embodiment of the present invention;

FIG. **19** shows an acceleration curve outputted from the motion detecting unit **101** of the operation indication outputting device in the fourth embodiment of the present invention when the user swings the operation indication outputting device once;

FIG. **20** shows an acceleration curve outputted from the motion detecting unit **101** when the user taps the operation indication outputting device once;

FIG. **21** is a flowchart showing motion analysis by the motion analyzing unit **102** in the fourth embodiment; and

FIG. **22** is a flowchart showing user action analysis by the user action analyzing unit **103** in the fourth embodiment.

DESCRIPTION OF THE PREFERRED EMBODIMENT(S)

The following is a description of the embodiments of the present invention with reference to the figures.

First Embodiment

FIG. **1** shows the configuration of an operation indication outputting device of the first embodiment of the present invention. The device includes a motion detecting unit **101**, a motion analyzing unit **102**, a user action analyzing unit **103**, and an operation determining unit **104**.

FIG. **2** shows the hardware construction of this operation indication outputting device. The motion detecting unit **101** is implemented by an acceleration sensor **201**, a signal amplifier **202**, and an A/D (analog-to-digital) converter **203**. The motion analyzing unit **102** and the user action analyzing unit **103** are implemented by a CPU **204**, a ROM **205**, and a RAM **206**. The operation determining unit **104** is implemented by the CPU **204**, the ROM **205**, the RAM **206**, and a communicating device **207**. The A/D converter **203**, the CPU **204**, the ROM **205**, the RAM **206**, and the communicating device **207** are connected to a bus **208**.

The motion detecting unit **101** samples acceleration levels in the acceleration sensor **201** at predetermined time intervals of, for instance, ½₅₆ second, amplifies analog voltage changes in the amplifier **202**, converts the amplification result to digital data in the A/D converter **203**, and outputs the digital data to the motion analyzing unit **102** and user action analyzing unit **103** via the bus **208**.

FIG. **3** shows the appearance of the operation indication outputting device and the placement of the acceleration sensor **201** of the motion detecting unit **101**.

In the figure, the motion detecting unit **101** has two acceleration sensors **301** and **302** which are equipped inside an enclosure **303**. The acceleration sensors **301** and **302** are placed respectively on detection axes **305** and **306** that are orthogonal to each other, to detect motion on a two-dimensional plane parallel to the front **304** of the enclosure **303**.

Here, to detect motion of the enclosure **303** in a single direction the motion detecting unit **101** may include only an acceleration sensor, while to detect motion of the enclosure **303** in a three-dimensional space another acceleration sensor may be placed on a detection axis orthogonal to the detection axes **305** and **306**, in addition to the acceleration sensors **301** and **302**.

Also, an action start button **308** may be placed on the surface **307** of the enclosure **303** to detect motion of the enclosure **303** while the user is pressing the button **308**.

Further, a contact sensor for sensing contact by the user may be equipped in the enclosure **303** to detect motion of the enclosure **303** while the user is holding the enclosure **303**.

Instead of being equipped with the above button and acceleration sensors, the operation indication outputting device may analyze motion of the enclosure **303** only when an output level of the acceleration sensor **201** exceeds a predetermined threshold value (ThHigh/ThLow).

FIGS. **4**A and **4**B show data outputted from the motion detecting unit **101**. Curve **401** shown in FIG. **4**A is an acceleration curve outputted, for example, from the acceleration sensor **302** when the enclosure **303** is swung once in the positive direction of the detection axis **306** and then stopped. The inverse of time taken for this motion, represented by frequency f1, is around 1–3 Hz.

Curve **402** shown in FIG. **4**B is an acceleration curve outputted, for example, from the acceleration sensor **301** when the enclosure **303** is tapped once in the positive direction of the detection axis **305**. Frequency f2 in this case is around 100–150 Hz.

Note here that to swing the enclosure **303** once is to move the enclosure **303** from one point to another, while to tap the enclosure **303** once is to strike the enclosure **303** with a single light blow.

Thus, a frequency differs depending on a type of an action, such as "swing" or "tap", made by the user against the enclosure **303**. The present invention reflects such differences of types of the user's actions on the contents of an operation indication to be outputted.

The motion analyzing unit **102** checks sign, magnitude, and inflection point in acceleration data outputted from the motion detecting unit **101** to analyze a direction, strength, and number of occurrence of a motion, and passes the analysis result to the operation determining unit **104**.

As is evident from the hardware construction in FIG. **2**, the motion analyzing unit **102** performs the analysis via the CPU **204** according to a program stored in the ROM **205**.

The analysis procedure by the motion analyzing unit **102** is explained below with reference to FIGS. **5** and **6**.

The analysis procedure in FIG. **5** is as follows. Here, the RAM **206** is used as a buffer for storing an analysis result.

In this example, acceleration levels sequentially outputted from the motion detecting unit **101** are represented by dashed line **701** in FIG. **7**A.

The motion analyzing unit **102** commences its motion analysis once the user has pressed the button **308** or the output from the acceleration sensor **301**/**302** has changed.

The motion analyzing unit **102** first clears the analysis result buffer **206** (**S501**) and initializes variables DataSum, MaxSum, and Counter to 0 (**S502**).

The motion analyzing unit **102** then acquires an acceleration level outputted from the motion detecting unit **101** (**S503**) and judges whether the acceleration level is above predetermined threshold value ThHigh (for the plus side) and

whether the acceleration level is below predetermined threshold value ThLow (on the minus side) (**S504**). If the acceleration level is neither greater than ThHigh nor smaller than ThLow, the procedure proceeds to step **S512**. Otherwise, the motion analyzing unit **102** adds the acceleration level to DataSum1 (**S505**). Here, DataSum is used for evaluating the integral of acceleration levels and so expresses velocity.

The motion analyzing unit **102** next judges whether the absolute value of DataSum exceeds threshold value ThresholdSum (**S506**). In FIG. **7**A, aThresholdSum is represented by single point chained line **702**, whereas DataSum is represented by velocity curve **703**.

When the absolute value of DataSum exceeds ThresholdSum at time T2 in FIG. **7**A, the motion analyzing unit **102** initializes Counter to 0 (**S507**) and judges whether the absolute value of DataSum exceeds the absolute value of MaxSum (**S508**). If the absolute value of DataSum does not exceed the absolute value of MaxSum, the procedure returns to step **S503**. Otherwise, the motion analyzing unit **102** assigns DataSum to MaxSum (**S509**) and returns to step **S503**. The process from step **S503** to step **S509** is repeated until time T3 in the present example.

If the absolute value of DataSum does not exceed ThresholdSum in step **S506** as in the case of time T1 or time T4, the motion analyzing unit **102** judges whether MaxSum=0 (**S510**). If MaxSum=0 as in the case of time T4, the motion analyzing unit **102** writes MaxSum into the analysis result buffer **206** (**S511**) and returns to step **S502**. If MaxSum=0, on the other hand, the motion analyzing unit **102** increments Counter by 1 (**S512**).

The motion analyzing unit **102** then judges whether Counter exceeds specified value EndCount (**S513**). When Counter≦EndCount, the procedure returns to step **S503**. When Counter>EndCount, the motion analyzing unit **102** judges whether the analysis result buffer **206** is empty (**S514**). If the analysis result buffer **206** is empty, the motion analysis procedure ends. Otherwise, the motion analyzing unit **102** notifies the operation determining unit **104** of the storage contents of the analysis result buffer **206** (**S515**) and ends the motion analysis procedure.

Here, EndCount is specified based on a sampling time interval in step **S503** and adjusted so that the analysis procedure ends when a few seconds lapse before time T1 or after time T4. EndCount may also be altered by the user.

MaxSum notified to the operation determining unit **104** in this example is the integral at time T3 in FIG. **7**A and denotes the maximum velocity when the enclosure **303** is swung.

The sign of MaxSum shows whether the enclosure **303** was swung in the positive direction or the negative direction, while the magnitude of MaxSum shows whether the enclosure **303** was swung lightly or strongly. Also, the fact that there is only one MaxSum in FIG. **7**A denotes that the enclosure **303** was swung once.

On the other hand, when a sequence of acceleration levels represented by dashed line **704** in FIG. **7**B is outputted from the motion detecting unit **101**, the motion analysis procedure is performed as follows.

In this case, after DataSum at time T5 is written into the analysis result buffer **206** as MaxSum in step **S511**, between time T6 and time T7 the absolute value of velocity curve **705** does not exceed ThresholdSum **702** and so Counter is incremented by 1 in step **S512** for each acceleration level during this period. Since Counter does not exceed EndCount at time T7, the procedure continues and eventually DataSum at time T8 is written into the analysis result buffer **206** as MaxSum in step **S511**.

Thus, for the sequence of acceleration levels shown in FIG. **7**B, the motion analyzing unit **102** notifies the operation determining unit **104** of both positive MaxSum and negative MaxSum.

When revealing the storage contents of the analysis result buffer **206** to the operation determining unit **104** in step **S515**, the motion analyzing unit **102** also notifies which of the acceleration sensors **301** and **302** the revealed analyses result is derived from.

While the motion analyzing unit **102** has received one acceleration level at a time from the motion detecting unit **101** in step **S503**, instead a sequence of acceleration levels may altogether be buffered in the RAM **206** to be later extracted one by one.

Also, as shown in FIG. **8**, step **S504** can be omitted if the motion detecting unit **101** is designed to output an acceleration level (with signal processing) when an output of the acceleration sensor **301**/**302** is either greater than ThHigh or smaller than ThLow.

In such a case, the motion detecting unit **101** outputs acceleration levels to the motion analyzing unit **102** and user action analyzing unit **103** during t1–t2 and t3–t4, and does not output acceleration levels during t0–t1 and t2–t3 and after t4.

Such a process by the motion detecting unit **101** or step **S504** by the motion analyzing unit **102** is effective to avoid unwanted processing for error acceleration levels of small magnitudes detected by the acceleration sensor **301**,**302**.

On the other hand, the analysis procedure in FIG. **6** that does not use the analysis result buffer **206** is as follows.

The motion analyzing unit **102** first initializes variables DataSum and MaxSum to 0 (**S601**) and judges whether the motion analyzing unit **102** is prompted to end the procedure (**S602**). If so, the motion analyzing unit **102** ends the motion analysis procedure. Here, the motion analyzing unit **102** ends the procedure when the user stops pressing the button **308** or after the operation determining unit **104** outputs an operation indication to an information processing apparatus.

If not yet prompted to end the procedure, the motion analyzing unit **102** samples an acceleration level outputted from the motion detecting unit **101** (**S603**) and adds the acceleration level to DataSum (**S604**).

The motion analyzing unit **102** then judges whether the absolute value of DataSum exceeds threshold value ThresholdSum (**S605**). If the absolute value of DataSum does not exceed ThresholdSum, the motion analyzing unit **102** judges whether MaxSum=0 (**S606**). If MaxSum=0, the procedure returns to step **S602**, while if MaxSum≠0, the procedure proceeds to step **S609**. When, on the other hand, the absolute value of DataSum exceeds ThresholdSum in step **S605**, the motion analyzing unit **102** further judges whether the absolute value of DataSum exceeds the absolute value of MaxSum (**S607**). If the absolute value of DataSum does not exceed the absolute value of MaxSum, the procedure returns to step **S602**. Otherwise, the motion analyzing unit **102** assigns DataSum to MaxSum (**S608**) and returns to step **S602**.

The motion analyzing unit **102** lastly notifies the operation determining unit **104** of MaxSum and returns to step **S601**.

The difference between the analysis procedure in FIG. **5** and the analysis procedure in FIG. **6** that uses the analysis result buffer **206** is merely that maximum and minimum

values of MaxSum are either sequentially or concurrently revealed to the operation determining unit **104**, so that they do not essentially differ.

Meanwhile, the user action analyzing unit **103** operates as follows.

Go prompted to commence user action analysis by the motion analyzing unit **102**, the user action analyzing unit **103** performs a fast Fourier transform (FFT) on acceleration levels outputted from the motion detecting unit **101** in time series and reveals a peak value of obtained frequencies to the operation determining unit **104**.

Here, if the peak value is smaller than a predetermined frequency (FREQ_LOW) on the low frequency side or greater than a predetermined frequency (FREQ_HIGH) on the high frequency side, the user action analyzing unit **103** prohibits the operation determining unit **104** to output an operation indication.

The user action analysis by the user action analyzing unit **103** is executed via the CPU **204** according to the program stored in the ROM **205**, in the same way as the motion analyzing unit **102**.

FIG. **9** is a flowchart showing the user action analysis procedure by the user action analyzing unit **103**.

The user action analyzing unit **103** acquires time series data of acceleration levels outputted from the motion detecting unit **101**, when prompted by the motion analyzing unit **102** to start the user action analysis (**S901**).

The user action analyzing unit **103** then performs a FFT on the acquired acceleration curve to obtain a frequency distribution (**S902**).

FIG. **10A** shows acceleration curve **1001** generated when the user continuously swings the enclosure **303**, whereas FIG. **10B** shows frequency distribution curve **1002** obtained by performing a FFT on acceleration curve **1001**. Peak point **1003** of frequency distribution curve **1002** is of 1–5 Hz.

FIG. **11A** shows acceleration curve **1101** generated when the user taps the enclosure **303** twice, whereas FIG. **11B** shows frequency distribution curve **1102** obtained by performing a FFT on acceleration curve **1101**. Peak point **1103** of frequency distribution curve **1102** is of 100–150 Hz.

The user action analyzing unit **103** notifies the operation determining unit **104** of a frequency at the main peak point of the obtained frequency distribution curve and an acceleration sensor that detected the pertinent acceleration (**S903**) before completing the procedure.

It should be noted that in step **S903** when the peak point of the obtained frequency distribution curve is below frequency FREQ_LOW on the low frequency side (shown by single point chained line **1004**) or above frequency FREQ_HIGH on the high frequency side (shown by single point chained line **1005**) in FIG. **10B** or **11B**, the user action analyzing unit **103** prohibits the operation determining unit **104** to output an operation indication, instead of revealing the peak frequency to the operation determining unit **104**. FREQ_LOW **1004** is set at 1 Hz for example. Suppose the enclosure **303** placed on an inclined surface moves accidentally. In such a case, a frequency distribution whose peak point is below FREQ_LOW is detected. Meanwhile, FREQ_HIGH **1005** is set at 200 Hz for example. Suppose the enclosure **303** is dropped or bumped against something. In such a case, a frequency distribution whose peak point is above FREQ_HIGH is detected. With the use of FREQ_LOW and FREQ_HIGH, it is possible to prevent the operation determining unit **104** from outputting a wrong operation indication to the information processing apparatus in the event of accidental movements such as above.

The operation determining unit **104** holds an operation determination table which has been stored in the ROM **205** in advance. Based on MaxSum received from the motion analyzing unit **102** and a peak value of a frequency distribution received from the user action analyzing unit **103**, the operation determining unit **104** reads an operation indication corresponding to the received MaxSum and peak value from the operation determination table and outputs the read operation indication to the information processing apparatus via the communicating device **207**. The communicating device **207** outputs an infrared signal expressing the operation indication to a light receiving unit (not illustrated) of the information processing apparatus via an infrared transmission line, through an aperture on the front **304** of the enclosure **303**.

FIG. **12** shows the contents of the operation determination table **1201**. Sensors **1** and **2** respectively correspond to the acceleration sensors **301** and **302**.

When a peak frequency notified by the user action analyzing unit **103** for sensor **1** is no greater than an established value such as 50 Hz, the operation determining unit **104** looks at "low frequency" **1202**, whereas the peak frequency is greater than the established value, the operation determining unit **104** looks at "high frequency" **1203**.

Also, when MaxSum notified by the motion analyzing unit **102** is a positive value while a peak frequency notified by the user action analyzing unit **103** for sensor **1** is no greater than the established value, the operation determining unit **104** looks at "positive direction" **1204**, whereas when MaxSum is a negative value, the operation determining unit **104** looks at "negative direction" **1205**. If at least one positive MaxSum and at least one negative MaxSum are notified by the motion analyzing unit **102**, "continuity" **1206** is referred to, whereas if there is no notification from the motion analyzing unit **102**, "0" **1207** is referred to in determining an operation indication. The same applies to sensor **2**.

Assume a peak value 6 Hz of frequencies detected by sensor **1** is notified from the user action analyzing unit **103** and a positive value of MaxSum is notified from the motion analyzing unit **102**, while no notification is made for sensor **2**. Then "up" **1208** corresponding to "positive direction" **1204** in "low frequency" **1202** of sensor **1** and "0" of sensor **2** is read as an operation indication and outputted to the information processing apparatus via the communicating device **207**.

Assume, on the other hand, a peak frequency 2 Hz and a positive value of MaxSum are notified for sensor **2** while no notification is made for sensor **1**. Then "right" **1209** corresponding to "0" **1207** of sensor **1** and "positive direction" in "low frequency" of sensor **2** is read as an operation indication and outputted to the information processing apparatus.

Thus, with the user's action of swinging the enclosure **303** that contains the operation indication outputting device, it is possible to indicate the information processing apparatus to move a cursor or a display on a display screen of the information processing apparatus in the same direction as the enclosure **303**.

As is evident from the operation determination table **1201**, the operation determining unit **104** can indicate any of 7 operations for one sensor, by distinguishing high frequency and low frequency based on data given from the user action analyzing unit **103** and further distinguishing no motion ("0"), positive direction, negative direction, and positive-negative continuity based on data given from the motion analyzing unit **102**. Accordingly, when two sensors

are mounted in the operation indication outputting device, the operation determining unit **104** can have a choice of 49 operation indications at the maximum.

In the present embodiment, however, to establish intuitive correspondence between the user's action and an operation of the information processing apparatus, 16 operation indications are provided that are made up of move indications (up, down, right, upper right, lower right, left, upper left, lower left, previous page, next page, top page), display indications (zoom in, zoom out), and commands (cancel operation, reexecute operation, select).

The overall operation of the operation indication outputting device of the first embodiment is explained below with reference to FIG. **13**.

Prompted by the user pressing the button **308** or the like, the motion detecting unit **101** starts motion detection and the motion analyzing unit **102** is instructed to commence motion analysis (S**1301**).

The motion analyzing unit **102** judges whether there is a motion (S**1302**). If there is a motion, the motion analyzing unit **102** instructs the user action analyzing unit **103** to start user action analysis (S**1303**). Otherwise, the procedure proceeds to step S**1306**.

On instructed to start the user action analysis, the user action analyzing unit **103** analyzes a frequency distribution and judges whether a peak value in the frequency distribution is below FREQ_LOW and whether the peak value is above FREQ_HIGH (S**1304**). If the peak value is either smaller than FREQ_LOW or greater than FREQ_HIGH, the procedure proceeds to step S**1306**. With this judgement, a malfunction of outputting a wrong operation indication is avoided when the enclosure **303** is accidentally dropped or bumped against something.

If the peak value is neither smaller than FREQ_LOW nor greater than FREQ_HIGH, the operation determining unit **104** determines the contents of an operation indication based on the motion analysis result and user action analysis result and outputs the determined operation indication to the information processing apparatus (S**1305**).

The motion detecting unit **101** judges whether the motion is stopped (S**1306**). If the motion has not been stopped, the procedure returns to step S**1302**. Otherwise, the motion detecting unit **101** instructs the motion analyzing unit **102** to stop the motion analysis (S**1307**) to complete the procedure.

While in the above embodiment the user action analyzing unit **103** has been implemented via the CPU **204** according to the program for performing a FFT in the ROM **205**, the FFT may be performed concurrently with the motion analysis of the motion analyzing unit **102**, by equipping a FFT arithmetic unit **1401** in the operation indication outputting device as shown in FIG. **14**.

Also, while the operation determination table **1201** has been stored in the ROM **205** in advance in the above embodiment, the operation determination table **120** may instead be stored in a storing device **1402** included in the operation determining unit **104** so that each user can set and dynamically change the contents of the table independently.

Though the operation determining unit **104** has sorted a peak frequency notified from the user action analyzing unit **103** as high frequency or low frequency in the above embodiment, the peak frequency may instead be sorted under three categories to further diversify operation indications.

Though the operation determining unit **104** has checked only a sign of MaxSum notified from the motion analyzing unit **102** in the above embodiment, the operation determining unit **104** may also check an absolute value of MaxSum to incorporate strength of the user's action into criteria for determining an operation indication.

While an operation indication has been outputted from the communicating device **207** to the information processing apparatus in the hardware construction in FIG. **2**, it is also possible to connect the bus **208** to the information processing apparatus to control the display screen and the like of the information processing apparatus, as shown in FIG. **15**.

In the above embodiment, the user action analyzing unit **103** has prohibited the operation determining unit **104** to output an operation indication when a peak frequency is above FREQ_HIGH on the high frequency side. At this point, MaxSum analyzed by the motion analyzing unit **102** corresponding to the peak frequency may be stored as a record on accidents of the operation indication outputting device. By keeping such a record, it is possible to analyze a cause of a failure of the operation indication outputting device in the event of the device being dropped or bumped against something.

Second Embodiment

The following is a description of an operation indication outputting device of the second embodiment of the present invention. This operation indication outputting device has a configuration similar to the first embodiment, except that the user action analyzing unit **103** here does not perform a FFT but calculates the amount of change in acceleration level to determine a type of the user's action.

The user action analyzing unit **103** acquires time series data (acceleration curve) **1601** of acceleration levels shown in FIG. **16** from the motion detecting unit **101** and calculates a mean value of a sequence of differential values (v/th that each represent the amount of change in acceleration level per unit of time. When the absolute value of an acceleration level exceeds the error level (i.e. when the acceleration level is either greater than ThHigh on the plus side or smaller than ThLow on the minus side), voltage v proportional to the acceleration level is outputted from the motion detecting unit **101** at certain sampling intervals (such as 2 msec). Which is to say, dt is constant, so that in each sampling the absolute difference {|v1−v0|, |v2−v1|, |v3−v2|, . . . |v19−v18|} in acceleration level (voltage) is calculated and a mean value of the calculated absolute differences is revealed to the operation determining unit **104**. Provided a sampling points are present within one sequence for which user action analysis is executed, output D is found as follows:

$$D = \frac{\sum_{i=1}^{n-1} |v_{i+1} - v_i|}{n-1} \quad \text{Equation 1}$$

(where n>1)

When a sequence of acceleration levels outputted from the motion detecting unit **101** forms a gentle acceleration curve as in FIG. **4A**, mean value D of differential values calculated in Equation 1 is small, while when the sequence of acceleration levels forms a sharp acceleration curve as in FIG. **4B**, mean value D of differential values calculated in Equation 1 is large. The operation determining unit **104** compares differential mean value D outputted from the user action analyzing unit **103** with a predetermined value to judge whether the user's action belongs to low frequency of slowly swinging the enclosure **303** or high frequency of

tapping the enclosure **303**. Based on this judgement, the operation determining unit **104** specifies an operation indication in the operation determination table **1201** in FIG. **12**.

Here, if differential mean value D calculated in Equation 1 is below predetermined threshold value ACCEL_LOW or above predetermined threshold value ACCEL_HIGH, the user action analyzing unit **103** prohibits the operation determining unit **104** to output an operation indication. ACCEL_LOW and ACCEL_HIGH respectively correspond to FREQ_LOW and FREQ_HIGH in the first embodiment and are used for preventing the output of a wrong operation indication caused by noise or the user dropping or bumping the enclosure **303**.

ACCEL_LOW and ACCEL_HIGH are set with reference to a maximum output value of the acceleration sensor **301**.**302**. For instance, setting 1/10 and 7/10 of the maximum output value respectively as ACCEL_LOW and ACCEL_HIGH can cancel operation indication output processing for an extremely slow or intense motion.

The user action analysis by the user action analyzing unit **103** of the present embodiment is explained below with reference to FIG. **17**.

The user action analyzing unit **103** acquires time series data of acceleration levels (**S1701**), calculates mean value D of differential values according to Equation 1 (**S1702**), and gives mean value D to the operation determining unit **104** (**S1703**), before completing the analysis procedure.

The overall operation of the operation indication outputting device of the second embodiment differs with the first embodiment shown in FIG. **13** only in that in step **S1304** the user action analyzing unit **103** judges whether differential mean value D is below ACCEL_LOW and whether differential mean value D is above ACCEL_HIGH.

Third Embodiment

The following is a description of an operation indication outputting device of the third embodiment of the present invention. Though this operation indication outputting device has roughly the same configuration as the first embodiment, the analysis method used by the user action analyzing unit **103** differs with the first embodiment. While in the first embodiment the user action analyzing unit **103** has performed a FFT on an acceleration curve outputted from the motion detecting unit **101** to obtain a frequency distribution, in the third embodiment the user action analyzing unit **103** performs a wavelet transform to analyze whether an acceleration curve outputted from the motion detecting unit **101** is made up of high frequency components or low frequency components, the analysis result then being given to the operation determining unit **104**.

A wavelet transform is a kind of filter that extracts only a waveform similar to a predetermined waveform. For details on the wavelet transform, see C. K. Chui (1997) *Wavelets: A Mathematical Tool for Signal Analysis* published by Society for Industrial & Applied Mathematics.

The wavelet transform is exemplified below with reference to FIG. **18**.

In the figure, on receiving acceleration curve **1801** from the motion detecting unit **101**, the user action analyzing unit **103** parallelly moves mother wavelet **1802** of detection target frequency (such as 100 Hz) in the time axis and calculates product **1803** of mother wavelet **1802** and each acceleration level. Here, a square wave is used as mother wavelet **1802**. A waveform starting from time **t0** in acceleration curve **1801** has a shape similar to mother wavelet **1802**, so that a product of mother wavelet **1802** and each acceleration level of this waveform is of large positive value. If, on the other hand, a waveform of an acceleration curve greatly differs with mother wavelet **1802** such as in the case of an acceleration curve of a few hertz in frequency, both positive and negative products are found, so that summation of a sequence of such products yields a value close to 0, indicating that the acceleration curve does not have a waveform of the detection target frequency. In contrast, when a wavelet transform is performed using a mother wavelet of 5 Hz in frequency, a waveform of an acceleration curve of low frequency close to 5 Hz can be detected. Therefore, the user action analyzing unit **103** performs the analysis using a plurality of mother wavelets of high frequencies of around 100 Hz and a plurality of mother wavelets of low frequencies of around 5 Hz and outputs the analysis result to the operation determining unit **104**.

Since a wavelet transform detects a strength and point of appearance of an acceleration curve, it can also be used for motion analysis by the motion analyzing unit **102**. Also, if the user's action involves different frequencies such as when the user first swings the enclosure **303** which is a motion of low frequency and then taps the enclosure **303** which is a motion of high frequency, such an action by the user is analyzable with a wavelet transform, so that the operation determining unit **104** can appropriately determine an operation indication for such a combination of motions. Further, in conducting user action analysis the user action analyzing unit **103** may perform a wavelet transform to detect high frequencies and perform the differential method of the second embodiment to detect low frequencies. Also, frequency bands to be detected are not limited to a high frequency band and a low frequency band but three or more frequency bands may be targeted for detection depending on the processing capability of the operation determining unit **104**. While the square wave has been used as the mother wavelet in performing a wavelet transform in this embodiment to reduce a calculation amount when multiplying the mother wavelet and the acceleration curve to be analyzed, instead the Daubechies wavelet may be used to improve detection accuracy.

Fourth Embodiment

The following is a description of an operation indication outputting device of the fourth embodiment of the present invention. Although the configuration of this operation indication outputting device is similar to the first embodiment, the main difference lies in that the motion analyzing unit **102** and the user action analyzing unit **103** exchange their analysis results in the fourth embodiment. The following description focuses on the difference with the other embodiments.

The motion analyzing unit **102** compares each acceleration level sequentially outputted from the motion detecting unit **101** with a predetermined reference value. The motion analyzing unit **102** then analyzes a direction of a motion based on a sign (plus/minus) of an acceleration level that first exceeds the reference value, and further analyzes a strength of the motion by calculating a period during which acceleration levels are above the reference value.

The user action analyzing unit **103** specifies a type of the user's action such as "swing" or "tap", based on the period during which the acceleration levels are above the reference value.

While the motion analyzing unit **102** in the first embodiment has evaluated the integral of acceleration levels outputted from the motion detecting unit **101**, in the present

embodiment a strength of a motion is analyzed by calculating a period during which acceleration levels are above the reference value, so that it is unnecessary to calculate the integral of acceleration levels. Hence the A/D converter **203** in the motion detecting unit **101** shown in FIG. **2** can be replaced with an analog comparator.

The procedure of the motion analyzing unit **102** and user action analyzing unit **103** of the fourth embodiment is explained below with reference to FIGS. **19** and **20**. FIG. **19** shows acceleration curve **1901** outputted, for instance, from the acceleration sensor **302** when the enclosure **303** is swung once in the positive direction of the detection axis **306** and then stopped. FIG. **20** shows acceleration curve **2001** outputted, for instance, from the acceleration sensor **302** when the enclosure **303** is tapped once in the positive direction of the detection axis **306**.

In these figures, the vertical axis represents voltage outputted from the acceleration sensor **302**, while the horizontal axis represents time.

First reference value ±SwingThreshold shown by broken lines **1902** and **1903** in FIG. **19** denotes a voltage corresponding to an acceleration level which is normally exceeded when the user swings the enclosure **303**. This reference value is set to correspond to 1 G (G denotes the acceleration of gravity) in this embodiment, although the value may be changed by the user or the operation indication outputting device itself. Since a voltage outputted from the acceleration sensor **302** is proportional to an acceleration level, the voltage is multiplied by a certain scale factor to get a value corresponding to 1 G.

First reference value ±SwingThreshold shown by broken lines **1902** and **1903** in FIG. **20** is the same as ±SwingThreshold in FIG. **19**. Second reference value ±TapThreshold shown by broken lines **2002** and **2003** in FIG. **20** denotes a voltage corresponding to an acceleration level which is normally exceeded when the user taps the enclosure **303**. This reference value is set to correspond to 2.5 G in this embodiment, although the value may be changed by the user or the operation indication outputting device itself.

TapThreshold is set to be larger than SwingThreshold, so that the absolute value of an acceleration level when the user swings the enclosure **303** never exceeds TapThreshold.

When acceleration curve **1901** shown in FIG. **19** is outputted from the motion detecting unit **101**, the motion analyzing unit **102** and the user action analyzing unit **103** operate as follows.

The motion analyzing unit **102** sequentially receives acceleration levels represented by acceleration curve **1901** from the motion detecting unit **101** at established time intervals of 2 msec for example, and judges whether the absolute value of a received acceleration level exceeds SwingThreshold. On judging that the absolute value of an acceleration level exceeds SwingThreshold at time T1, the motion analyzing unit **102** starts measuring a period during which SwingThreshold is exceeded, and in the meantime analyzes a direction of a motion based on a sign (plus in this example) of the acceleration level at time T1. The motion analyzing unit **102** also judges whether the absolute value of an acceleration level exceeds TapThreshold (see FIG. **20**) which is larger than SwingThreshold. Since a type of the user's action associated with acceleration curve **1901** is "swing", there is no acceleration level whose absolute value exceeds TapThreshold in FIG. **19**.

Subsequently, on judging that the absolute value of an acceleration level becomes below SwingThreshold at time T2, the motion analyzing unit **102** analyzes a strength of the motion based on period t1 from T1 to T2 during which SwingThreshold is exceeded. The motion analyzing unit **102** then reveals period t1 to the user action analyzing unit **103** and notifies the user action analyzing unit **103** that the absolute value of the acceleration level has become below SwingThreshold.

After time T2 the motion analyzing unit **102** continues to judge whether the absolute value of an acceleration level received from the motion detecting unit **101** exceeds SwingThreshold. On judging that the absolute value of an acceleration level exceeds SwingThreshold at time T3, the motion analyzing unit **102** notifies the user action analyzing unit **103** of this judgement.

SwingThreshold is exceeded during period t3 from time T3 to time T4, in spite of which period t3 is not measured this time, since acceleration levels during this period derive from inverse acceleration caused when the user stopped moving the enclosure **303**. Then, on judging that the absolute value of an acceleration level becomes below SwingThreshold at time T4, the motion analyzing unit **102** notifies the user action analyzing unit **103** of this judgement.

Since acceleration curve **1901** in FIG. **19** originates from the user's action of swinging the enclosure **303** once, after T2 there is no acceleration level whose absolute value exceeds SwingThreshold apart from those caused by the inverse acceleration. However, if an acceleration level whose absolute value is above SwingThreshold appears after T4, such an acceleration level is analyzed in counting the number of times the user swings the enclosure **303**.

On instructed by the user action analyzing unit **103** to pass the above analysis result to the operation determining unit **104**, the motion analyzing unit **102** reveals the direction, strength, and number of occurrence of the motion to the operation determining unit **104**.

When notified by the motion analyzing unit **102** that the absolute value of the acceleration level has become below SwingThreshold at time T4, the user action analyzing unit **103** measures period t4 up to a point when the motion analyzing unit **102** notifies that SwingThreshold is exceeded again or a point when a predetermined period elapses. The predetermined period, such as 100 msec, is a period sufficient for assuming that there is no more action such as "swing" or "tap" by the user.

Once the predetermined period has lapsed since time T4, the user action analyzing unit **103** analyzes a type of the user's action based on the period, notified by the motion analyzing unit **102**, during which SwingThreshold or TapThreshold is exceeded. Concurrently, the user action analyzing unit **103** instructs the motion analyzing unit **102** to reveal the analysis result such as the direction of the motion to the operation determining unit **104**.

If notified by the motion analyzing unit **102** that both SwingThreshold and TapThreshold were exceeded, the user action analyzing unit **103** primarily judges the type of the user's action as "tap", since an acceleration curve generated as a result of the user tapping the enclosure **303** exceeds both TapThreshold and SwingThreshold without exception.

In the case of acceleration curve **1901** in FIG. **19**, the user action analyzing unit **103** is notified by the motion analyzing unit **102** that SwingThreshold was exceeded and of period t1 during which SwingThreshold was exceeded. Accordingly, once the predetermined period such as 100 msec has elapsed from time T4, the user action analyzing unit **103** analyzes the type of the user's action as "swing" and notifies the operation determining unit **104** of the analysis result.

Here, if a period during which SwingThreshold was exceeded is shorter than a fixed first period such as 50 msec

or a period during which TapThreshold was exceeded is longer than a fixed second period such as 20 msec, the user action analyzing unit **103** does not inform the type of the user's action but notifies the operation determining unit **104** of occurrence of a malfunction. Similarly, if the period during which SwingThreshold is exceeded is longer than a fixed third period such as 400 msec, the user action analyzing unit **103** notifies the operation determining unit **104** of occurrence of a malfunction instead of informing the type of the user's action.

The first period is used here to avoid mistakenly outputting an operation indication when short vibrations which are not intended by the user occur. The third period is used to avoid mistakenly outputting an operation indication when the operation indication outputting device is in a running car or the like with continuous acceleration of a few seconds. Equally, the second period is used to avoid mistakenly outputting an operation indication in the event of an accident or breakdown of the operation indication outputting device, since a period during which TapThreshold is exceeded when the user taps the enclosure **303** with his or her finger(s) is normally in the domain of around a few milliseconds to 10 milliseconds.

When, on the other hand, acceleration curve **2001** in FIG. **20** is outputted from the motion detecting unit **101**, the motion analyzing unit **102** and the user action analyzing unit **103** operate as follows.

The motion analyzing unit **102** sequentially receives acceleration levels represented by acceleration curve **2001** from the motion detecting unit **101** and judges whether the absolute value of a received acceleration level exceeds SwingThreshold. On judging that the absolute value of an acceleration level exceeds SwingThreshold at time T5, the motion analyzing unit **102** starts measuring a period during which SwingThreshold is exceeded. The motion analyzing unit **102** also analyzes a direction of a motion based on a sign (plus in this example) of the acceleration level at time T5.

Next, the motion analyzing unit **102** judges whether the absolute value of an acceleration level exceeds TapThreshold. On judging that the absolute value of an acceleration level exceeds TapThreshold at time T6, the motion analyzing unit **102** starts measuring a period during which TapThreshold is exceeded. During the measurement of this period, the motion analyzing unit **102** stops measuring the period during which SwingThreshold is exceeded. On judging that the absolute value of an acceleration level becomes below TapThreshold at time T7, the motion analyzing unit **102** reveals period t6 during which TapThreshold was exceeded to the user action analyzing unit **103**. The motion analyzing unit **102** then resume measuring the period during which SwingThreshold is exceeded until time T8, the measured period thus being the difference of subtracting period t6 from period t5. Although this period (t5−t6) is revealed to the user action analyzing unit **103** along with the notification that the absolute value of an acceleration level has become below SwingThreshold at time T8, the user action analyzing unit **103** does not use this period for analyzing a type of the user's action. After time T8, there is no acceleration level whose absolute value exceeds SwingThreshold in FIG. **20**. On instructed by the user action analyzing unit **103** to notify the above analysis result to the operation determining unit **104**, the motion analyzing unit **102** reveals the direction and strength of the motion to the operation determining unit **104**. When two periods, namely a period during which SwingThreshold is exceeded and a period during which TapThreshold is exceeded, are measured as in the present case, only the direction and strength corresponding to the period t6 during which TapThreshold was exceeded are revealed to the operation determining unit **104**.

On notified by the motion analyzing unit **102** that the absolute value of the acceleration level has decreased below SwingThreshold at time T8, the user action analyzing unit **103** measures period t8 up to a point when the motion analyzing unit **102** notifies that SwingThreshold is exceeded again or a point when the predetermined period elapses. If the predetermined period elapses while there is no notification from the motion analyzing unit **102** that SwingThreshold is exceeded again, the user action analyzing unit **103** instructs the motion analyzing unit **102** to announce the analysis result to the operation determining unit **104**.

Meanwhile, the user action analyzing unit **103** makes sure that revealed period t6 during which TapThreshold was exceeded is not longer than the second period, and notifies the operation determining unit **104** that the type of the user's action is "tap".

The operation determining unit **104** reads an appropriate operation indication from the operation determination table **1201** based on the analysis results given from the motion analyzing unit **102** and user action analyzing unit **103** and outputs the read operation indication to the information processing apparatus via the communicating device **207**, in the same way as the first to third embodiments. Note that in the present embodiment "low frequency" and "high frequency" (such as **1202** and **1203**) in the operation determination table **1201** are replaced respectively with "swing" and "tap".

Also, if notified by the user action analyzing unit **103** of occurrence of a malfunction, the operation determining unit **104** does not read an operation indication from the operation determination table **1201** even when it has received an analysis result from the motion analyzing unit **102**.

The procedure by the motion analyzing unit **102** and user action analyzing unit **103** of the fourth embodiment is explained below with reference to FIGS. **21** and **22**.

First, the motion analyzing unit **102** initializes each of the following variables to 0 (S**2102**)

Variable accFlag shows whether the absolute value of an acceleration level outputted from the motion detecting unit **101** exceeds a predetermined reference value such as SwingThreshold.

Variable swingcounter is used to measure a period during which SwingThreshold is exceeded. Since an acceleration level is outputted per 2 msec in the present embodiment, doubling swingcounter yields a period in milliseconds during which SwingThreshold is exceeded.

Variable tapCounter is used to measure a period during which TapThreshold is exceeded. Doubling tapcounter yields a period in milliseconds during which TapThreshold is exceeded.

Variable idleCounter is actually held by the user action analyzing unit **103**, in spite of which it is initialized concurrently with the variables of the motion analyzing unit **102**. This variable is used to measure a period during which the reference value (SwingThreshold) is not exceeded after it was once exceeded. Doubling idlecounter yields a period in milliseconds during which the reference value is not exceeded.

Variable swingDirect shows a sign of an acceleration level starting from which SwingThreshold is exceeded, and is given a value of variable direct.

Variable tapDirect shows a sign of an acceleration level starting from which TapThreshold is exceeded, and is given a value of variable direct in the same way as swingDirect.

Variable direct shows a sign of an acceleration level starting from which a reference value is exceeded. When the sign of the acceleration level is plus, "1" is assigned to direct, while when the sign of the acceleration level is minus, "−1" is assigned to direct, thereby indicating a direction of a motion.

The motion analyzing unit **102** sequentially receives acceleration levels outputted from the motion detecting unit **101** per 2 msec and assigns a received acceleration level to variable acc that shows an acceleration level (S2104). The motion analyzing unit **102** then compares the absolute value of acc with first reference value SwingThreshold (S2106). If the absolute value of acc is above SwingThreshold, the motion analyzing unit **102** sets accFlag at 1 and simultaneously instructs the user action analyzing unit **103** to set idleCounter at 0 (S2108). The user action analyzing unit **103** accordingly sets idleCounter to 0.

The motion analyzing unit **102** next judges whether acc is larger than 0 (S2110). If acc is larger than 0, the motion analyzing unit **102** sets direct at 1 (S2112), while if acc is no larger than 0, direct is set at −1 (S2114).

The motion analyzing unit **102** further judges whether the absolute value of acc exceeds second reference value TapThreshold (S2116). When the absolute value of acc is no larger than TapThreshold, the motion analyzing unit **102** judges whether swingDirect is 0 (S2118). If swingDirect is 0, direct is assigned to swingDirect (S2120), while if swingDirect is not 0, it is judged whether swingDirect is equal to direct (S2122). When swingDirect is equal to direct, swingcounter is incremented by 1 (S2124), while when swingDirect is not equal to direct, the motion analyzing unit **102** judges whether instructed by the user action analyzing unit **103** to reveal an analysis result to the operation determining unit **104** (S2126). If the user action analyzing unit **103** has not yet instructed the motion analyzing unit **102** to reveal the analysis result, the procedure returns to step S2104. Otherwise, the motion analyzing unit **102** informs the operation determining unit **104** of swingDirect that shows a direction of a motion and swingcounter that shows a strength of the motion (S2128), and complete the procedure.

When judging in step S2116 that the absolute value of acc exceeds TapThreshold, the motion analyzing unit **102** judges whether tapDirect is 0 (S2130). If tapDirect is 0, direct is assigned to tapDirect (S2132), while if tapDirect is not 0, tapDirect is compared with direct (S2134). When tapDirect is equal to direct, tapcounter is incremented by 1 (S2136). Otherwise, the procedure proceeds to step S2126.

If in step S2106 the absolute value of acc is judged as not exceeding SwingThreshold, the motion analyzing unit **102** judges whether accFlag is 1 (S2138). When accFlag is not 1, the procedure proceeds to step S2126, while when accFlag is 1, the procedure shifts to the user action analyzing unit **103** at step S2202.

The user action analyzing unit **103** increments idleCounter by 1 (S2202) and judges whether idleCounter exceeds specified value IDLE_TIME (S2204). If idleCounter does not exceed IDLE_TIME, the procedure returns to step S2104. Otherwise, the user action analyzing unit **103** instructs the motion analyzing unit **102** to inform the operation determining unit **104** of the analysis result (S2206). IDLE_TIME referred to here represents a period sufficient for assuming that there is no longer an action such as "swing" or "tap" by the user. IDLE_TIME is set, for instance, at 50 corresponding to 100 msec.

The user action analyzing unit **103** then judges whether tapDirect is 0 (S2208). If tapDirect is not 0, it is judged whether tapcounter is larger than 0 and smaller than TAP_TIME_MAX that corresponds to the above second period (S2210). TAP_TIME_MAX is set, for instance, at 10 as acceleration levels are outputted per 2 msec from the motion detecting unit **101**. When tapCounter is either no larger than 0 or no smaller than TAP_TIME_MAX, the user action analyzing unit **103** notifies the operation determining unit **104** of occurrence of a malfunction (S2212) and returns to step S2102. When, on the other hand, tapCounter is larger than 0 and smaller than TAP_TIME_MAX, the user action analyzing unit **103** notifies the operation determining unit **104** that the type of the user's action is "tap" (S2214), before returning to step S2102.

If it is judged in step S2208 that tapDirect is 0, the user action analyzing unit **103** judges whether swingDirect is 0 (S2216). When swingDirect is 0, the procedure returns to step S2102. Otherwise, the user action analyzing unit **103** judges whether swingcounter is larger than SWING_TIME_MIN corresponding to the above first period and smaller than SWING_TIME_MAX corresponding to the above third period (S2218). SWING_TIME_MIN and SWING_TIME_MAX are respectively set, for instance, at 5 and 200, given that acceleration levels are outputted per 2 msec from the motion detecting unit **101**.

When in step S2218 swingcounter is either no larger than SWING_TIME_MIN or no smaller than SWING_TIME_MAX, the user action analyzing unit **103** notifies the operation determining unit **104** of occurrence of a malfunction (S2220) and returns to step S2102. Meanwhile, when swingcounter is larger than SWING_TIME_MIN and smaller than SWING_TIME_MAX, the user action analyzing unit **103** notifies the operation determining unit **104** that the type of the user's action is "swing" (S2222), before returning to step S2102.

While for ease of explanation the above embodiment has assumed that acceleration levels are outputted from one acceleration sensor, the procedure may also be performed with a plurality of acceleration sensors as in the first to third embodiments.

While in the above embodiment two reference values SwingThreshold and TapThreshold have been used to analyze whether a type of the user's action is "swing" or "tap", more reference values may be used to increase types of the user's actions to be analyzed. By doing so, operation indications outputted from the operation determining unit **104** can be further diversified.

In the above embodiment the user action analyzing unit **103** has judged occurrence of a malfunction when a period during which TapThreshold was exceeded is longer the second period. Alternatively, a value (e.g. 5 G) approximately corresponding to double TapThreshold may be set as a threshold value, so that when an acceleration level whose absolute value is above this threshold value is detected, the user action analyzing unit **103** judges the acceleration level as deriving from a malfunction caused by the user dropping or bumping the enclosure **303** against something. In the same way, when an acceleration level whose absolute value is below 1 G is detected, the user action analyzing unit **103** may judge the acceleration level as deriving from a malfunction.

While in the first to fourth embodiments the motion detecting unit **101** has used acceleration sensors, the motion detecting unit **101** may instead use angular acceleration sensors. Suppose the acceleration sensor **301** that detects acceleration in the detection axis **305** is replaced with an angular acceleration sensor. In such a case, when the user

rotates the enclosure **303** by hand, angular acceleration of a rotary motion originated from the user's wrist is detected, with the direction axis **305** being the tangential direction.

Applications

The following are applications of the operation indication outputting device of the above embodiments.

1. Application to Mobile Phones

When the user swings or taps a mobile phone into which the operation indication outputting device is incorporated, the mobile phone can perform an operation such as follows according to an operation indication given from the operation indication outputting device.

(1) When the user taps the mobile phone twice which is emitting an incoming call sound, the mobile phone stops the sound and switches to manner mode (tapping the mobile phone just once may cause a malfunction).

(2) When the user taps the mobile phone twice which is emitting an alarm sound, the mobile phone stops the sound.

(3) When the user taps the mobile phone twice which is originating a call, the mobile phone stops the call. Thus, the user can swiftly cancel a call to a wrong number.

(4) To search a telephone directory registered in the mobile phone for a desired number, the mobile phone switches a display if swung, and calls to the desired number if tapped when the desired number is displayed.

(5) When the user swings and then taps the mobile phone which is displaying electronic mail or the like on its display screen, the mobile phone starts and then stops scrolling the display.

(6) An electronic pet displayed on the mobile phone does "shake" when the mobile phone is swung, and does "sit" when the mobile phone is tapped.

(7) A backlight color on the display screen of the mobile phone is changed when the mobile phone is swung.

(8) The mobile phone produces a different sound depending on how strong and in which direction the user swings the mobile phone and which part of the mobile phone the user taps on.

(9) The mobile phone generates random numbers when swung and stops generating the random numbers when tapped, thereby offering a kind of game.

(10) By sending information on the user's action of swinging or tapping the mobile phone to a call destination mobile phone, the mobile phone manipulates a display on a display screen of the call destination mobile phone, has the call destination mobile phone produce an effect sound, or has the call destination mobile phone vibrate.

2. Application to Portable Terminals (Computers)

When the user swings or taps a portable terminal into which the operation indication outputting device is incorporated, the portable terminal can perform an operation such as follows according to an operation indication given from the operation indication outputting device.

(1) A selection cursor on a menu displayed on the portable terminal is moved when the user swings the portable terminal, and stopped to select from the menu when the user taps the portable terminal.

(2) When the user wearing a wristwatch-type PDA (Personal Digital Assistance) swings his/her wrist from side to side, latest information is displayed on a display screen of the PDA.

3. Application to Remote Controllers

When the user swings or taps a remote controller into which the operation indication outputting device is incorporated, the remote controller can output an indication such as follows to a controlled apparatus according to an operation indication given from the operation indication outputting device.

(1) TV Remote Controller

A TV remote controller outputs a channel switch indication to a TV when swung from side to side, outputs a volume control indication when swung up and down, and outputs a power off indication when tapped twice.

(2) VCR Remote Controller

While tape is stopped in a VCR (videocassette recorder), a VCR remote controller outputs a play indication to the VCR when tapped, outputs a fast-forward indication when swung from side to side, and outputs a rewind indication when swung up and down.

While tape is being played in the VCR, the VCR remote controller outputs a stop indication to the VCR when tapped, outputs a fast-forward play indication when swung from side to side, and outputs a rewind play indication when swung up and down.

While tape is being rewound in the VCR, the VCR remote controller outputs a rewind stop indication to the VCR when tapped.

(3) Lighting Remote Controller

A lighting remote controller outputs a light amount control indication to the lighting when swung from side to side, and outputs a power off indication when tapped.

(4) MD (mini disk) Remote Controller

An MD remote controller outputs a power on indication or a power off indication to an MD when tapped twice, and outputs a track start search indication when swung from side to side.

It should be noted that while in the first to fourth embodiments the motion analyzing unit **102**, user action analyzing unit **103**, and operation determining unit **104** have performed their respective procedures according to the program stored in the **ROM 205** in FIG. **2**, this program may be recorded on a storing medium such as a CD-ROM or distributed on the Internet, with it being possible to incorporate the above described function of the present invention into an operation indication outputting device which by itself cannot distinguish types of the user's actions as the operation indication outputting device of the present invention.

Although the present invention has been fully described by way of examples with reference to the accompanying drawings, it is to be noted that various changes and modifications will be apparent to those skilled in the art. Therefore, unless such changes and modifications depart from the scope of the present invention, they should be construed as being included therein.

What is claimed is:

1. An operation indication outputting device for outputting an operation indication to an information processing apparatus to have the information processing apparatus perform processing based on the outputted operation indication, the operation indication outputting device comprising:

storing means for storing operation indications that each correspond to a combination of a type of a user's action and at least one of a direction, a strength, and a number of occurrence of a motion of the operation indication outputting device caused by the user's action;

motion detecting means for detecting a motion of the operation indication outputting device caused by the user's action;

motion analyzing means for analyzing at least one of a direction, a strength, and a number of occurrence of the detected motion,

user action analyzing means for analyzing a type of the user's action that causes the detected motion; and

outputting means for reading, from the storing means, an operation indication corresponding to a combination of an analysis result by the motion analyzing means and a analysis result by the user action analyzing means, and outputting the read operation indication to the information processing apparatus.

2. The operation indication outputting device of claim 1, wherein the motion detecting means detects acceleration levels of the motion of the operation indication outputting device over time, and

wherein the motion analyzing means analyzes at least one of the direction, the strength, and the number of occurrence of the motion by integrating, with respect to time, the acceleration levels outputted from the motion detecting means.

3. The operation indication outputting device of claim 2, wherein the user action analyzing means includes

a fast fourier transform analyzing unit for obtaining a frequency distribution by performing a fast Fourier transform on a curve produced by graphing the acceleration levels outputted from the motion detecting means against time, to analyze the type of the user's action.

4. The operation indication outputting device of claim 3, wherein the user action analyzing means further includes an output prohibiting unit for prohibiting the outputting means to output the operation indication if a peak value in the obtained frequency distribution is any of below a first frequency and above a second frequency.

5. The operation indication outputting device of claim 2, wherein the user action analyzing means includes

a differential analyzing unit for differentiating, according to a predetermined equation, a curve produced by graphing the acceleration levels outputted from the motion detecting means against time, to analyze the type of the user's action.

6. The operation indication outputting device of claim 5, wherein the user action analyzing means further includes an output prohibiting unit for prohibiting the outputting means to output the operation indication if a mean value of differential values calculated by the differential analyzing unit is any of below a first threshold value and above a second threshold value.

7. The operation indication outputting device of claim 2, wherein the user action analyzing means includes

a wavelet transform analyzing unit for detecting specific frequency components by performing a wavelet transform on a curve produced by graphing the acceleration levels outputted from the motion detecting means against time, to analyze the type of the user's action.

8. The operation indication outputting device of claim 7, wherein the storing means further stores operation indications that each correspond to an order of a plurality of types of the user's actions,

wherein the user action analyzing means further includes an action sequence analyzing unit for analyzing types of the user's actions that cause the motion, according to an order in which the detected specific frequency components appear, and

wherein the outputting means includes

an order-corresponding operation indicating unit for reading, from the storing means, an operation indication corresponding to an order of the types of the user's actions analyzed by the action sequence analyzing unit, and outputting the read operation indication to the information processing apparatus.

9. The operation indication outputting device of claim 2, wherein the user action analyzing means includes

a time analyzing unit for measuring, for each of a plurality of reference values, time during which the reference value is exceeded by absolute values of a sequence of acceleration levels among the acceleration levels outputted from the motion detecting means, to analyze the type of the user's action.

10. The operation indication outputting device of claim 9, wherein the user action analyzing means further includes

an output prohibiting unit for prohibiting the outputting means to output the operation indication if at least one of absolute values of the outputted acceleration levels is any of below a first threshold value and above a second threshold value.

11. The operation indication outputting device of claim 1, wherein the motion detecting means detects acceleration levels of the motion of the operation indication outputting device over time,

wherein for each of a plurality of reference values, when the reference value is exceeded by absolute values of a sequence of acceleration levels among the acceleration levels outputted from the motion detecting means, the motion analyzing means analyzes a sign of an acceleration level whose absolute value first exceeds the reference value in the sequence of acceleration levels, and measures time during which the reference value is exceeded by the absolute values of the sequence of acceleration levels, thereby analyzing at least one of the direction, the strength, and the number of occurrence of the motion, and

wherein the user action analyzing means analyzes the type of the user's action based on the time measured by the motion analyzing means.

12. The operation indication outputting device of claim 11,

wherein the plurality of reference values are made up of a first reference value and a second reference value larger than the first reference value, and

wherein the user action analyzing means includes

an output prohibiting unit for prohibiting the outputting means to output the operation indication, any of if time during which the first reference value is exceeded is shorter than predetermined first time and if time during which the second reference value is exceeded is longer than predetermined second time.

13. The operation indication outputting device of claim 12,

wherein the first reference value is set at a value corresponding to an acceleration level which is to be detected when the user swings the operation indication outputting device,

wherein the second reference value is set at a value corresponding to an acceleration level which is to be detected when the user taps the operation indication outputting device, and

wherein the user action analyzing means analyzes whether the type of the user's action is "swing" or "tap".

14. The operation indication outputting device of claim 1, wherein the motion detecting means detects angular acceleration levels of the motion of the operation indication outputting device over time, and

wherein the motion analyzing means analyzes at least one of the direction, the strength, and the number of occurrence of the motion by integrating, with respect to time, the angular acceleration levels outputted from the motion detecting means.

15. The operation indication outputting device of claim 14,

wherein the user action analyzing means includes

a fast Fourier transform analyzing unit for obtaining a frequency distribution by performing a fast Fourier transform on a curve produced by graphing the angular acceleration levels outputted from the motion detecting means against time, to analyze the type of the user's action.

16. The operation indication outputting device of claim 1,

wherein the motion detecting means detects angular acceleration levels of the motion of the operation indication outputting device over time,

wherein for each of a plurality of reference values, when the reference value is exceeded by absolute values of a sequence of angular acceleration levels among the angular acceleration levels outputted from the motion detecting means, the motion analyzing means analyzes a sign of an angular acceleration level whose absolute value first exceeds the reference value in the sequence of angular acceleration levels, and measures time during which the reference value is exceeded by the absolute values of the sequence of angular acceleration levels, thereby analyzing at least one of the direction, the strength, and the number of occurrence of the motion, and

wherein the user action analyzing means analyzes the type of the user's action based on the time measured by the motion analyzing means.

17. The operation indication outputting device of claim 16,

wherein the plurality of reference values are made up of a first reference value and a second reference value larger than the first reference value, and

wherein the user action analyzing means includes

an output prohibiting unit for prohibiting the outputting means to output the operation indication, any of if time during which the first reference value is exceeded is shorter than predetermined first time and if time during which the second reference value is exceeded is longer than predetermined second time.

18. The operation indication outputting device of claim 1,

wherein the operation indication outputting device is incorporated into a mobile phone that is the information processing apparatus, and

wherein a processing mode of the mobile phone is changed according to the operation indication outputted from the outputting means.

19. A mobile phone that incorporates an operation indication outputting device for outputting an operation indication to the mobile phone to have the mobile phone perform processing based on the outputted operation indication, the operation indication outputting device comprising:

storing means for storing operation indications that each correspond to a combination of a type of a user's action and at least one of a direction, a strength, and a number of occurrence of a motion of the operation indication outputting device caused by the user's action;

motion detecting means for detecting a motion of the operation indication outputting device caused by the user's action;

motion analyzing means for analyzing at least one of a direction, a strength, and a number of occurrence of the detected motion;

user action analyzing means for analyzing a type of the user's action that causes the detected motion; and

outputting means for reading, from the storing means, an operation indication corresponding to a combination of an analysis result by the motion analyzing means and an analysis result by the user action analyzing means, and outputting the read operation indication to the mobile phone,

wherein a processing mode of the mobile phone is changed according to the operation indication outputted from the outputting means.

20. A computer-readable storing medium storing a program executed by an operation indication outputting device that is equipped with a detecting unit for detecting a motion of the operation indication outputting device caused by a user's action and outputs an operation indication to an information processing apparatus to have the information processing apparatus perform processing based on the outputted operation indication, the program comprising:

a motion analyzing step for analyzing at least one of a direction, a strength, and a number of occurrence of the motion detected by the detecting unit;

a user action analyzing step for analyzing a type of the user's action that causes the detected motion; and

an outputting step for reading, from an storing unit which stores operation indications that each correspond to a combination of a type of the user's action and at least one of a direction, a strength, and a number of occurrence of a motion of the operation indication outputting device caused by the user's action, an operation indication corresponding to a combination of an analysis result obtained in the motion analyzing step and an analysis result obtained in the user action analyzing step, and outputting the read operation indication to the information processing apparatus.

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